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BIOLOGY

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AS PER PMC SYLLABUS

- Topic-wise Complete Syllabus
- Comprehensive Course Revision
- Detailed Explanation of Topics
- Tables, Flow Sheets & Diagrams
- Critical Concepts; Critical Thinking

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TOPIC-1 » BIO-DIVERSITY (ACELLULAR LIFE / VARIETY OF LIFE)

COURSE CONTENT

- Classification of viruses
- Discovery of Viruses
- Structure of Viruses
- Viral Diseases (For example AIDS)

CLASSIFICATION OF VIRUSES

- Virus classification is generally based upon;

(i) Host
(ii) Morphology
(iii) Genome
(iv) Mode of action
(v) Mode of replication

The internationally agreed system of virus classification is based on the structure and composition of the virus particle (virion).

CRITICAL CONCEPT!

Ability of Viruses to Infect Life Forms:
Viruses infecting cells from the three domains of life, Archaea, Bacteria and Eukarya, share homologous features, suggesting that viruses originated very early in the evolution of life.

Classification of Viruses Based Upon Host	
Host	**Description**
Bacteriophages	It attacks bacteria. It is a **DNA** virus with a polyhedral head and a tail
Plant viruses	More than 2,000 types of viral plant diseases are known. Most plant viruses discovered till to date including tobacco mosaic virus (TMV), having an **RNA genome.** Many viruses have rod shaped capsid like TMV, potato yellow dwarf virus.
Animal viruses	Animal viruses occur as parasites in animals. In many viral infections viruses attack and destroy certain cells in the human body causing the symptoms and diseases. • Viruses cause foot and mouth disease in livestock. • *Rous sarcoma* virus causes cancer in animals. • Poxvirus causes small pox. • Picornavirus causes polio, hepatitis A etc. • Paramyxovirus causes measles and mumps.

Classification of Viruses Based Upon Structure	
(i) On The Bases of Capsid	
Helical capsid	Viruses having a helical capsid with overall shape of a rigid rod e.g. tobacco mosaic virus
Polyhedral capsid	Viruses having helical a polyhedral capsid with a glycoprotein spikes at each vertex e.g. Adenoviruses
Envelope	Viruses having an outer envelope studded with glycoprotein spikes e.g. Influenza Viruses

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Complex capsid	Viruses having a complex capsid consisting of a polyhedral head and a tail apparatus, e.g. Bacteriophage.
(ii) On The Bases of Genomes	
Double-stranded (dsDNA)	E.g. Poxvirus causes smallpox virus, and cowpox virus.
Single-stranded DNA (ssDNA)	E.g. Parvovirus, causes mild rashes.
Double-stranded RNA (dsRNA)	E.g. Reovirus causes diarrhea.
Single-stranded RNA (ssRNA)	Serves as mRNA e.g. Togavirus (Rubella virus
ssRNA	Template for mRNA synthesis e.g. Orthomyxovirus (influenza virus
ssRNA	ssRNA act as template for DNA synthesis e.g. Retrovirus (HIV)

DISCOVERY OF VIRUSES

Scientist	Year	Achievement
Edward Jenner	1796	1st vaccine against small pox (viral disease).
Charles Chamberland	1884	Filterable nature of rabies viruses.
Ivanowski	1892	Filterable nature of TMV
W.M.Stanley	1935	Isolation, purification and crystallization of TMV
TwortandD'Herelle	1915, 1917	Discovery of bacteriophages

CRITICAL THINKING

1. _____ **of viruses was a major breakthrough in understanding viruses:**
 A. Purification B. Characterization
 C. Crystallization D. Isolation

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STRUCTURE OF VIRUSES

Characteristics of Viruses

- Viruses are ***non-cellular infectious entities*** which contain either RNA or DNA genome, normally encased in proteinaceous coat. This suggested that, unlike other pathogens, viruses are of simple chemical composition.
- They show the characteristic of both living and non-living things. The living characteristics of viruses are;

1. Viruses occur in different ***variety of strains.***
2. They have their own genetic material in the form of either ***DNA or RNA that can undergo mutation.***
3. They reproduce using the metabolic machinery of the host cell they infect.
4. They enter living organism and cause disease i.e., obligate intracellular parasites.

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5. They get ***destroyed by UV rays***.

- The non-living characteristics of viruses are;

1. They lack cellular structure, co-enzyme and enzyme system and do not have metabolic activity of their own.
2. They can be ***crystallized and stored in bottles***.
3. They ***do not respire***. They behave as non-living, inert infectious particles outside the host.

- Viruses ***cannot be grown on artificial media.***
- They can reproduce only in animal and plant cells or in microorganisms, where they reproduce by replication (a process by which many copies or replicas of virus are formed).
- All viruses are generally ***resistance to broad range of available antibiotics*** such as penicillin, streptomycin and others.
- ***Prions*** are infectious particles made only of proteins and cause mysterious brain infection in man and mad cow infection in cow.
- ***Viroids*** are minute particles of RNA and lack protein coat. They cause diseases in both plants and animals.

Size

Viruses are extremely small infectious agents, which can only be seen under an ***electron microscope.***

- They range in size from ***250nm*** of ***poxviruses*** to the ***20nm*** of ***parvoviruses***.
- They are ***10*** to ***1000 times smaller than most bacteria***, so they can pass through the pores of filter, from which bacteria cannot pass.
- Viruses have a very simple structure. A complete, mature and infectious particle is known as ***virion.*** Primarily, it can be divided into two parts i.e. ***core*** and ***coat***.

Central Core

- The core is inner part of virion which consists of viral genome and various proteins (enzymes).
- Genome is the genetic material, which is ***either DNA or RNA*** and may be single stranded or double stranded.
- ***Core proteins*** include one or more enzymes that facilitate the virus in its mode of action with host body. For example, retroviruses and hepatitis B virus contain ***reverse transcriptase*** which converts single stranded RNA genome into double stranded DNA genome.

Outer Coat

- The coat is the outer covering of viral particle which consists of ***capsid and envelope.***
- The capsid the protective coat of proteins surrounding the central core. Capsid is made up of protein subunits known as ***capsomeres.***

CRITICAL CONCEPT!

Viroids:
Viroid is an infectious particle smaller than any of the known viruses. Particle consists only of an extremely small circular ssRNA, lacking the protein coat. Viroids appear to be transmitted mechanically from one cell to another through cellular debris.

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- The number of capsomeres is specific to a particular kind of virus. For example, 162 capsomeres are present in capsid of herpes virus and 252 in the capsid of adenovirus.
- There are two forms of symmetry in virus capsid i.e. ***cubical or helical***. When the capsomeres are arranged in 20 triangles, it is called icosahedral (polyhedral or spherical). When the capsomeres are arranged in a hollow coil that appears rod shaped, it is called helical.
- A few viruses have an additional ***lipoprotein envelope*** around the capsid which is derived from the cell surface membrane of the host and also contain virally encoded proteins. Non-enveloped viruses are known as ***naked viruses.***

CRITICAL THINKING?

2. What are prions?

A. Misfolded versions of normal brain protein
B. Tiny molecules of RNA that infect plants
C. Viral DNA that has had to attach itself to the host genome
D. Viruses that invade bacteria

VIRAL DISEASES

Disease	Virus	Source of Transmission	Symptoms	Immunization
Herpes Simplex (Oral herpes)	Herpes simplex type 1 virus (DNA enveloped virus)	Oral secretions or physical contact with sores or by objects (Toothbrush, utensils)	Blisters/ Vascular lesions in epithelial layers of ectodermal tissue. Most commonly in mouth, lips, and skin sites.	Antiviral drugs/ Avoid contact
Measles	RNA enveloped virus (Paramyxovirus)	Coughing & Sneezing	Fever, runny nose, cough, red eyes, red flat rashes on skin	Auto-immunity, Vaccination
Mumps	RNA enveloped virus (Paramyxovirus)	Coughing & sneezing	Fever, muscle pain, headache, painful swelling of parotid glands	Auto-immunity, Vaccination
Poliomyelitis	Polio virus/ Enterovirus (RNA non-enveloped virus, in spherical capsid). Smallest known virus	Oro-fecal route	Damage to motorneurons of spinal cord&leading to paralysis of limbs	Vaccination / Physiotherapy

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Hepatitis A (Infectious)	Picornavirus (RNA non-enveloped virus)	Oro-fecal route	Acute infection (Nausea, vomiting, diarrhea, jaundice)	Vaccination/ Good hygiene
Hepatitis B (Serum)	Hepadnavirus (DNA enveloped virus)	Blood, Sexual contact, Mother to newborn	Acute (vomiting, yellowish skin, tiredness, dark urine, abdominal pain) &chronic (No symptoms, livercirrhosis&liver cancer)	Vaccination/ Alpha interferons/ Screening of blood
Hepatitis C (Infusion)	Flavivirus (RNA enveloped virus)	Blood	Chronic (ocassionallyfever, dark urine, abdominal pain, yellow skin) withcirrhosis&liver cancer.	No Vaccination/ Alpha interferon & Ribavirin/ Screening of blood
Hepatitis D	Viroid	Blood or serum	Same as hepatitis B	Same as hepatitis B
Hepatitis E	RNA non-enveloped virus	Oro-fecal route	Acute infection (Nausea, vomiting, diarrhea, jaundice)	Good hygiene
AIDS	RNA enveloped virus	Blood/ Sexual contact	Opportunistic infections, Swollenlymphnodes	Vaccination NOT available

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CRITICAL THINKING!

3. **Naturally occurring endonucleases are very effective against:**
 A. Protozoans B. Viruses
 C. Bacteria D. Bacteriophages

ACQUIRED IMMUNO DEFICIENCY SYNDROME

- Retroviruses are associated with tumor production in animals like fowl, rodents and cats.
- Human immunodeficiency virus which causes acquired immunodeficiency syndrome (AIDS) is a retrovirus.
- May be ***non- specific*** in their action but usually infect those cells containing ***specific receptors***.

CRITICAL CONCEPT!

Retroviruses:
Retroviruses are having two RNA molecules, which may be positive sense RNA and/or negative sense RNA.

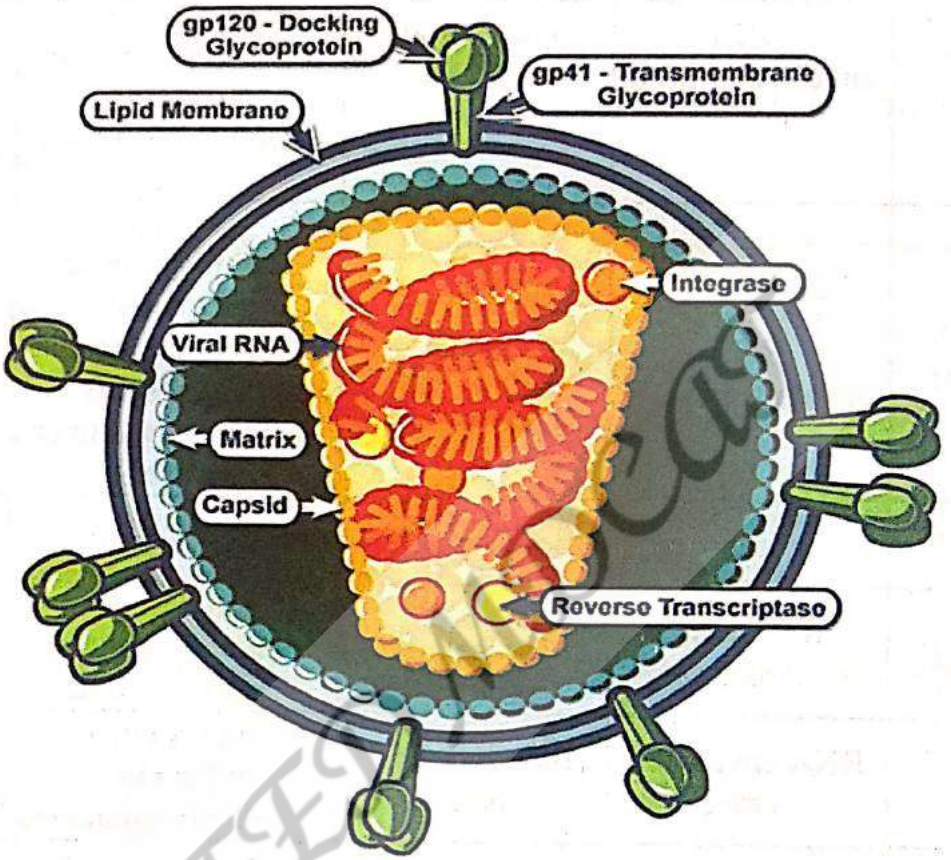
Structure of Human Immunodeficiency Virus

- They are ***spherical, 100nm*** in diameter.
- The outer covering is a ***lipoprotein envelope*** which consists of two layers of lipids; different proteins are embedded in the viral envelope, forming '***spikes***', consisting of the

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and gp41 is critical for the cell fusion process.

- Beneath envelope, another protein shell is present which is made up of ***matrix proteins***. It lies between envelope and capsid.
- The HIV capsid is somewhat ***conical shaped*** which is composed of capsomeres.
- The HIV core contains two single strands of RNA molecules and enzymes needed for HIV replication, such as ***reverse transcriptase, integrase, protease***.



Host Specificity

- Primary hosts of HIV are ***helper T-lymphocytes*** (CD4 cells).
- In addition, macrophages and certain brain cells may also be affected.

Mode of Transmission

- By intimate ***sexual contact*** (virus present in body secretions and blood, which gets entry in recipient blood from minor wear and tears, more common in homosexuals).
- Contact with blood and breast feeding.
- ***Prick*** of an infected needle or surgical instruments (problem for health care providers).

Acquired Immunodeficiency Syndrome (AIDS)

AIDS first reported in ***young homosexual males***, having one or more complex symptoms like severe pneumonia, vascular cancer, sudden weight loss, swollen lymph nodes and immune deficiency or decreased immune functions.

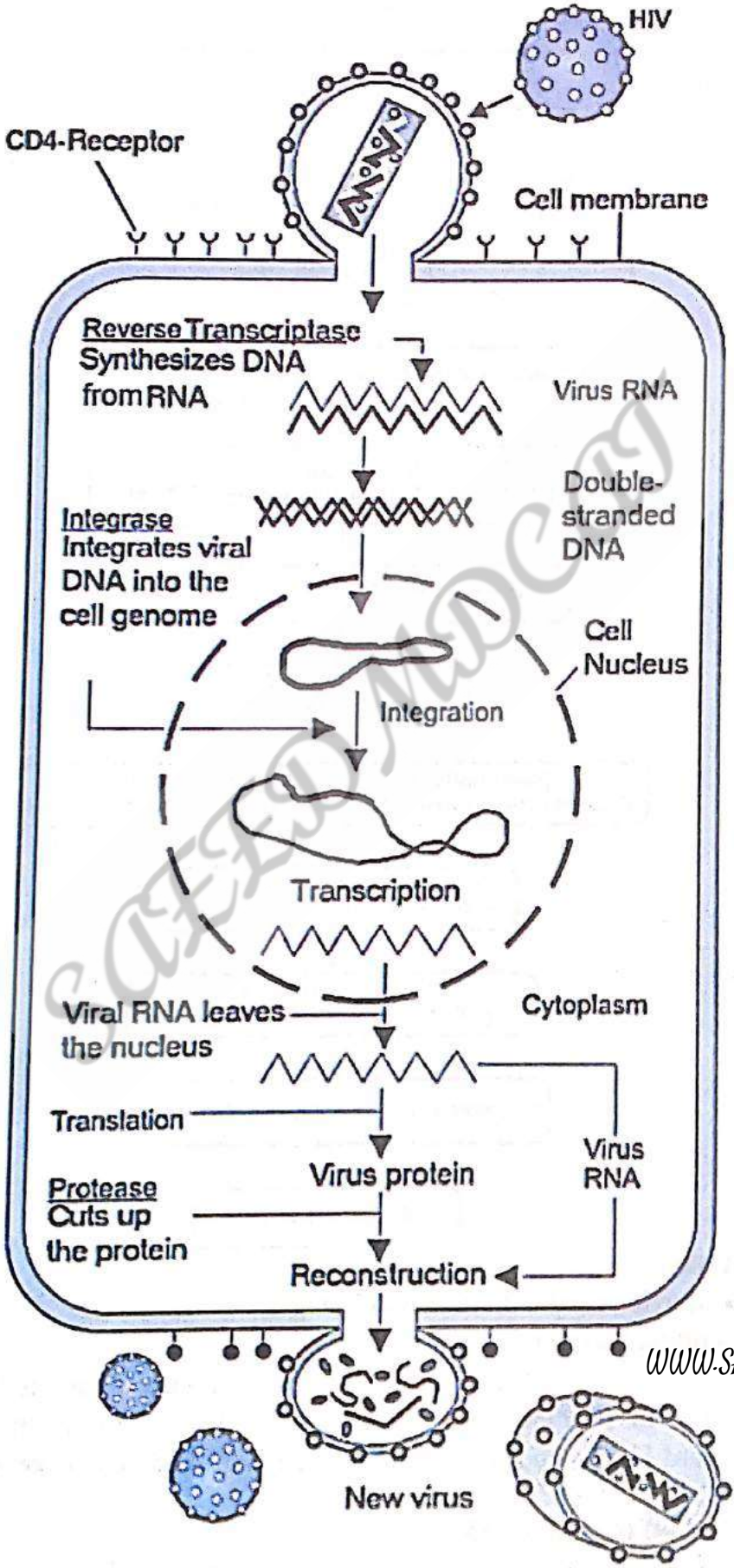
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CRITICAL THINKING?

4. **Which of the following viruses is having maximum rate of replication?**
 A. Herpes Simples Virus
 B. HIV
 C. Polio Virus
 D. Hepatitis A Virus

Life Cycle / Infectious Cycle of HIV

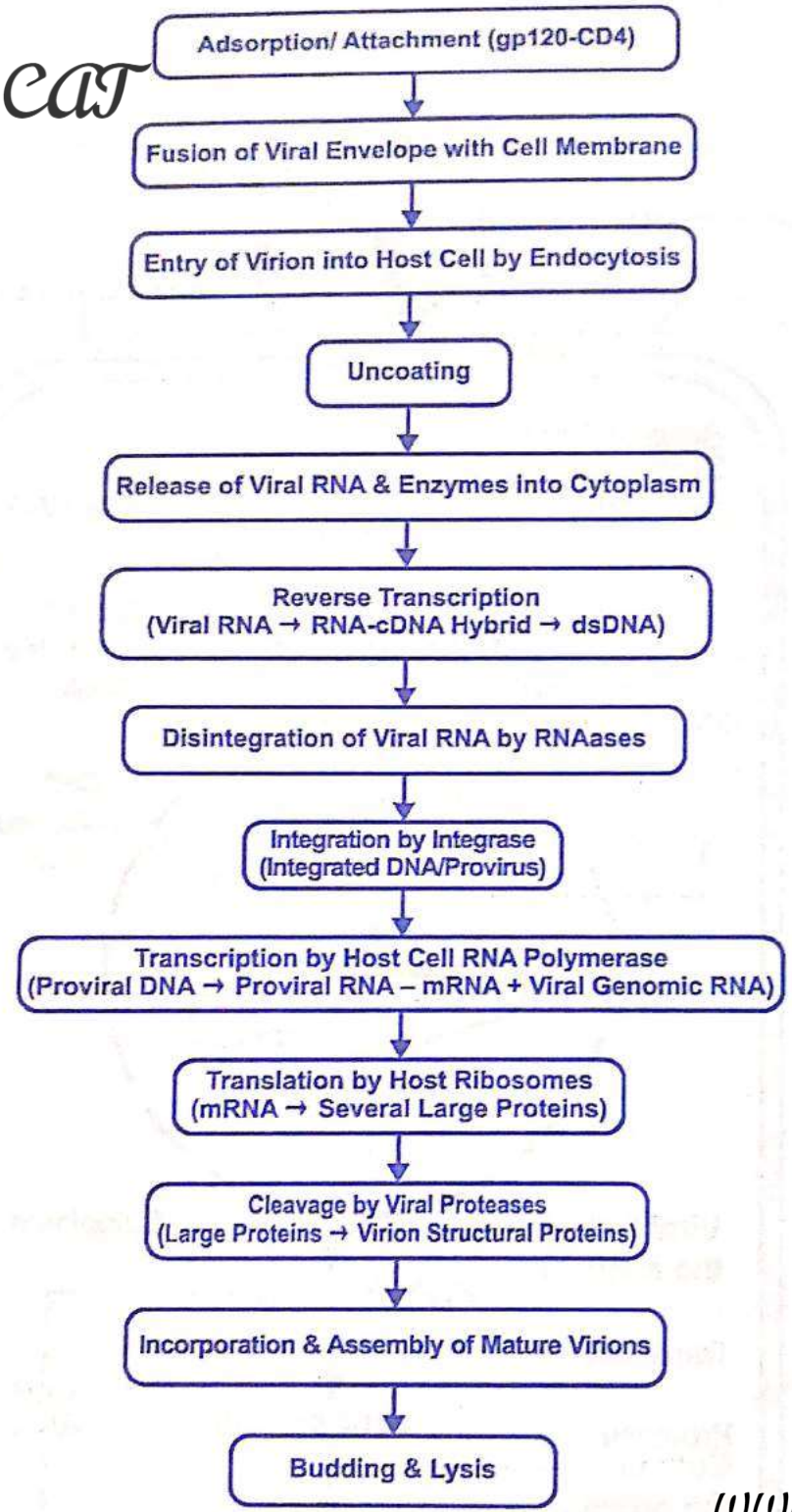
The steps of HIV life cycle are shown in the following diagram.



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Flow Chart

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Symptoms of AIDS

An HIV infection can be divided into 3 stages:

(i) Asymptomatic Carrier

- Fever, chills, aches (continued pain), swollen lymph glands and itchy rashes.
- These symptoms disappear and there are no symptoms for 9 months or longer.
- The standard HIV blood test for the presence of antibody becomes positive during this stage.

(ii) AIDS Related Complex (ARC)

- Swollen lymph glands in neck, armpit or groin that persist for months. Other symptoms

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include night sweats, persistent cough, flu, persistent diarrhea, loss of memory, inability to think clearly, loss of judgment and depression.

(iii) Full Blown AIDS

- It is the final stage. In this stage, there is severe weight loss and weakness due to persistent diarrhea and usually one of the several opportunistic infections i.e. Kaposi's sarcoma (cancer or lesion on skin), fungal infection, viral infection, gastrointestinal disease, respiratory disease, nervous system and eye diseases).

Treatment of AIDS

Antiretroviral therapy (ART) is done for treatment. It is not a cure but it controls virus and increases life span of infected people.

Control Measures Against HIV Transmission

- Avoid sharing syringes, toothbrushes, towel and blades.
- Use of sterile needles, syringes and surgical instruments.
- Avoid prohibited sexual contacts.
- Screening of blood and blood products before transfusion.

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TOPIC-2 BIOENERGETICS

COURSE CONTENT

- Photosynthesis
- Role of Light, Photosynthetic pigments, Water and CO_2
- Mechanism of Photosynthesis and Light Dependent Reactions (Production of ATP via ETC\Chemiosmosis)
- Light Independent Reactions (Calvin Cycle)
- Cellular Respiration (Aerobic and Anaerobic Reactions)
- Mechanism of Aerobic Respiration and Glycolysis
- Pyruvic Acid Oxidation, Krebs cycle
- Respiratory Chain/Electron Transport Chain and Oxidative Phosphorylation

PHOTOSYNTHESIS

- Photosynthesis can be defined as the process in which energy poor inorganic oxidized compounds of carbon (CO_2) and hydrogen (mainly H_2O) are reduced to energy rich carbohydrate i.e. glucose (sugar) using the light energy that is absorbed and converted into chemical energy by chlorophyll and some other photosynthetic pigments.

Photosynthetic Reactants and Products

- Consider the following equation of photosynthesis;

$$6CO_2 + 12H_2O + \text{Light} \xrightarrow{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

This equation shows that carbon dioxide, water and light are the reactants while glucose and oxygen are the products. Water appears on both sides of the equation because water is used as reactant in some reactions and released as product in other. However, because there is no net yield of H_2O, we can simplify the summary equation of photosynthesis for purpose of discussion:

$$6CO_2 + 6H_2O + \text{Light} \xrightarrow{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2$$

Relation between Photosynthesis and Respiration

- Chemical equation of photosynthesis is almost exactly opposite to the overall equation of aerobic respiration ($C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$).
- Photosynthesis uses the products of respiration and respiration uses the products of photosynthesis.
- Photosynthesis occurs only during daytime, whereas respiration goes on day and night.

Light Variations and Compensation Point

- During darkness, leaves and other actively metabolizing cells respire and utilize oxygen and release carbon dioxide.
- At dawn and dusk, when light intensity is low, the rate of photosynthesis and respiration may for a short time, equal one another. Thus oxygen released from photosynthesis is just the amount required for cellular respiration. Also the carbon dioxide released by respiration just equals the quantity required by photosynthesizing cells.

 At this moment there is no net gas exchange between the leaves and the atmosphere. This is termed as ***compensation point.***

 As the light intensity increases, so does the rate of photosynthesis and hence the requirement for more carbon dioxide increases which respiration alone cannot supply. Similarly, the oxygen produced during photosynthesis is more than the need of the respiring cells, so the result is the net release of oxygen coupled with the uptake of carbon dioxide.

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ROLE OF LIGHT

Role of Light and Types of Spectra

- Sunlight is an electromagnetic or radiant form of energy. The full range of electromagnetic radiation in the universe is called ***electromagnetic spectrum***.
- Photosynthetic pigments are the substances that absorb ***visible light*** (380-750 nm wavelengths).
- Light is form of energy called electromagnetic energy or radiations. It behaves as waves as well as sort of particles called ***photons***.
- The effectiveness of a particular wavelength of light for the process of photosynthesis primarily depends upon its absorption by the plants. As different wavelengths/colours of visible light are differently absorbed by various photosynthetic pigments, therefore, each wavelength has its own effectiveness for the process of photosynthesis.
- Not all the light falling on leaf is absorbed. Only about 1% of the light falling on the leaf surface is absorbed, the rest is reflected or transmitted.

Spectrum of Light for Plants

There are two types of spectrum:

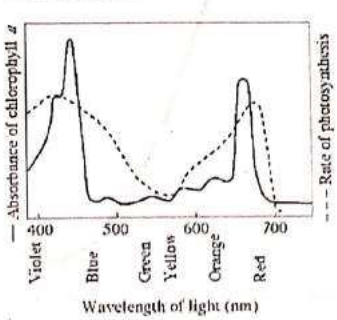
- Absorption spectrum
- Action spectrum

Absorption Spectrum

- Graph showing relative absorption of different wavelengths of light by different photosynthetic pigments is called absorption spectrum.
- Absorption spectrum of chlorophylls indicates that absorption is maximum in blue and red parts of the spectrum, two absorption peaks being at around ***430 nm and 670 nm*** respectively.
- Absorption peaks of carotenoids are different from those of chlorophylls, as they show more absorption at ***430nm to 500nm***.

CRITICAL THINKING

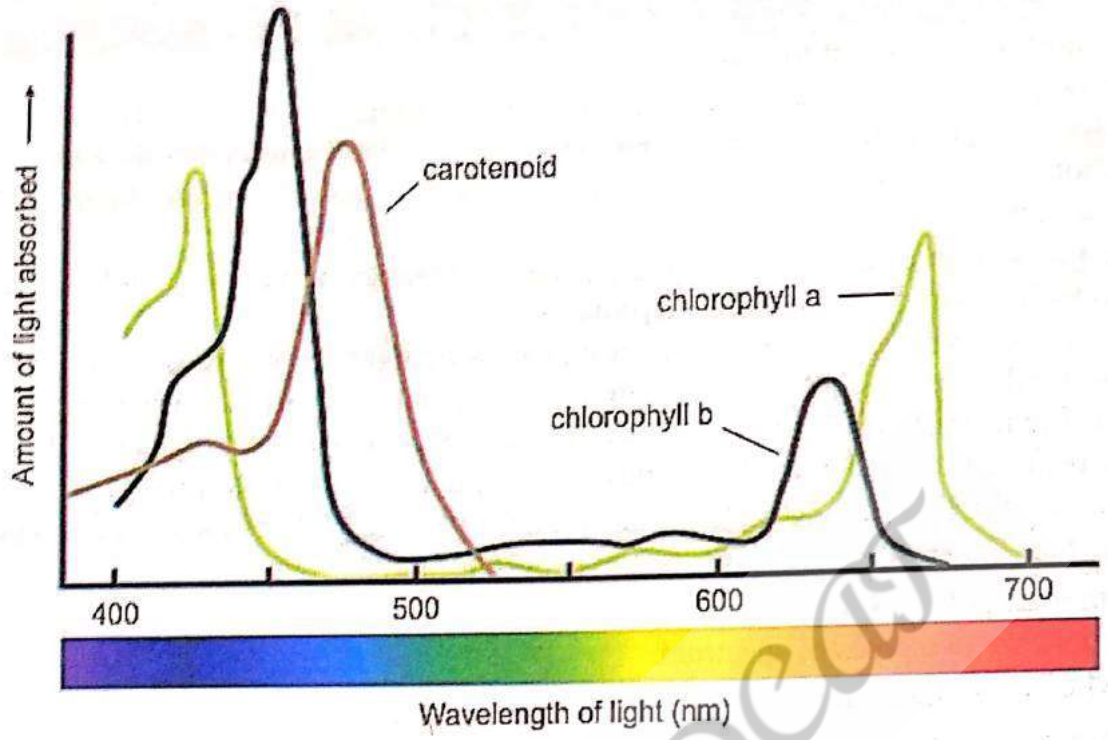
1. Figure shows the absorption spectrum for chlorophyll and the action spectrum for photosynthesis. Why are they different?



A. Green and yellow wavelengths inhibit the absorption of red and blue wavelengths
B. Bright sunlight destroys photosynthetic pigments
C. Oxygen given off during photosynthesis interferes with the absorption of light
D. Other pigments absorb light in addition to chlorophyll 'a'

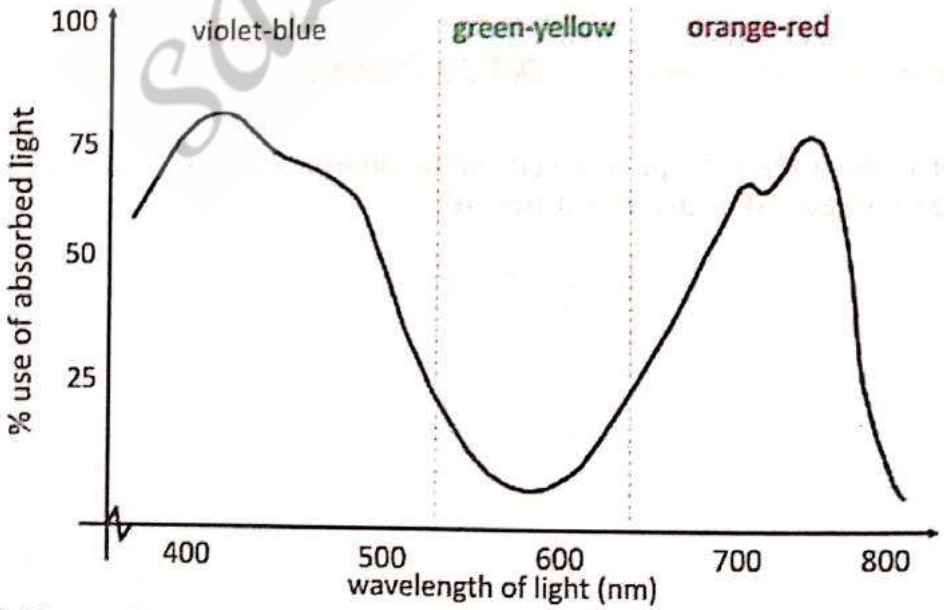
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Action Spectrum

- Graph showing relative effectiveness of different wavelengths of light in driving photosynthesis is called action spectrum of photosynthesis.
- The first action spectrum was obtained by German biologist T.W. Engelmann in 1883. He worked on *Spirogyra*.
- Action spectrum can be obtained by illuminating plant with light of different wavelengths and then estimating relative CO_2 consumption or oxygen release during photosynthesis.
- Analysis of action spectrum indicates ***that blue (430nm) and red (670nm)*** wavelengths of light are most effective for the process of photosynthesis.



Comparison of Absorption and Action Spectra

- Action spectrum of photosynthesis corresponds to absorption spectrum of chlorophyll. The same two peaks and the valley are obtained for absorption of light as well as for CO_2 consumption.

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- However, the action spectrum of photosynthesis does not parallel the absorption spectrum of chlorophyll exactly.
- Photosynthesis in the most absorbed range is more than the absorption itself.
- Likewise, photosynthesis in 500-600 nm (including green light) is more than the absorption of green light by chlorophylls. This difference occurs because of the accessory pigments, carotenoids.
- When equal intensities of light are given, there is more photosynthesis in red than in blue part of spectrum.

Feature	Absorption Spectrum	Action Spectrum
Peaks	Narrow	Broader
Valley	Broader and deep	Narrow and not deep

ROLE OF PHOTOSYNTHETIC PIGMENTS

- Pigment is any substance that absorbs light energy. All the wavelengths that are absorbed by the pigments are ***disappeared***.
- A particular pigment shows only those wavelengths which are reflected back.
- All the pigments that take part in photosynthesis are ***embedded in thylakoid membranes***.

Chlorophylls

- They are ***main photosynthetic pigments*** of plants.
- They are ***insoluble in water*** but are ***soluble in organic solvents*** like carbon tetrachloride, alcohol etc.
- Chlorophyll 'a', 'b', 'c' and 'd' are found in eukaryotic photosynthetic plants and algae.
- ***Bacteriochlorophylls*** are found in photosynthetic bacteria.
- They mainly ***absorb violet-blue and orange-red wavelengths.*** Green, yellow and indigo wavelengths are least absorbed by chlorophylls and transmitted or reflected.

CRITICAL CONCEPT!

Evolution of Chlorophyll:
Conversion of bacteriochlorophyll to chlorophyll a is the main basic point in evolution that shifted the life from reducing environment to oxidizing environment.

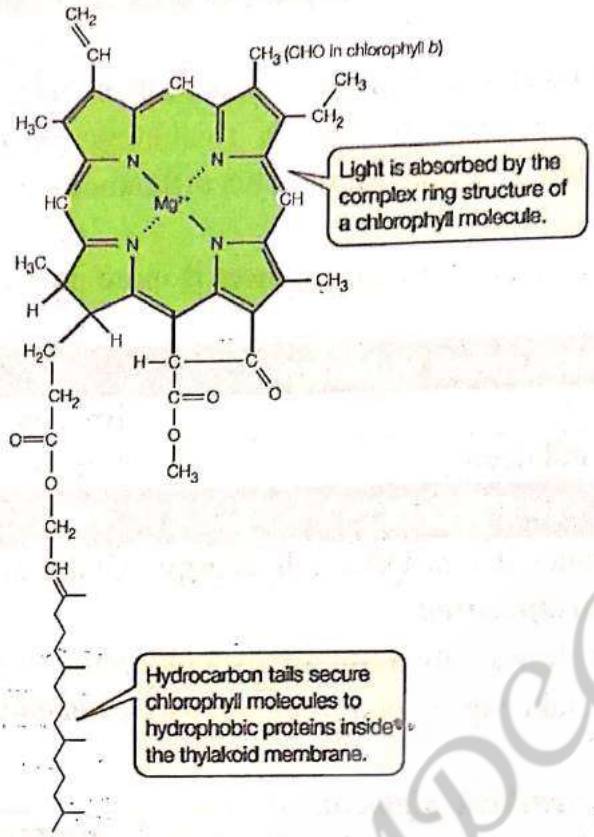
Structure

- A chlorophyll molecule has two parts i.e. ***hydrophilic head*** and a ***hydrophobic hydrocarbon tail.***
- ***Hydrophilic head*** is flat, square, light absorbing complex porphyrin ring or tetrapyrrole ring structure containing magnesium as central metal ion, which is coordinated with nitrogen.
- ***Hydrophobic hydrocarbon tail*** is long, anchoring phytol ($C_{20}H_{39}$). The chlorophyll molecule is embedded in the hydrophobic core of thylakoid membrane by this tail.

Chlorophyll 'a' and 'b'

- Of all the chlorophylls, chlorophyll a is the most abundant and the most important photosynthetic pigment.
- It takes part directly in the light dependent reactions.

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Differences between Chlorophyll 'a' and Chlorophyll 'b'

Features	Chlorophyll 'a'	Chlorophyll 'b'
Molecular Formula	$C_{55}H_{72}O_5N_4Mg$	$C_{55}H_{70}O_6N_4Mg$
Functional Group	$-CH_3$ (methyl group)	-CHO (carbonyl group)
Occurrence	All photosynthetic organisms except photosynthetic bacteria	In association with chlorophyll a in all green plants and green algae
Forms	Differ slightly in their red absorbing peaks e.g. 670,680,690,700 nm	No such different forms
Colour	Blue – green	Yellow- green

Carotenoids-Accessory Pigments

- Carotenoids are yellow and red to orange pigments.
- They absorb strongly the ***blue-violet range***.
- ***Carotenoids and chlorophyll b*** are called accessory pigments, since they absorb light and transfer the energy to chlorophyll a, which then initiate the light reaction.
- ***Carotenoids → Chlorophyll 'b' → Chlorophyll 'a'***
- There are two types of carotenoids; ***carotenes and xanthophylls***. The carotenes are orange-red pigments composed of isoprenoid units and are found in all photosynthetic eukaryotes. The most wide spread and important carotene is β-carotenes.
- Xanthophylls are yellow in colour and are also composed of isoprenoid units.

Functions

- They broaden the spectrum of light that provides energy for photosynthesis.
- Some of these may ***protect chlorophyll*** by absorbing and dissipating intense light.
- Similarly, carotenoids may ***protect human eye***.

ROLE OF WATER IN PHOTOSYNTHESIS

Role of Water

Oxygen released during photosynthesis comes from water and is an important source of atmospheric oxygen, which most organisms need for ***aerobic respiration*** and thus for obtaining energy to live.

Discovery about Involvement of Water in Oxygen Production

- In 1930s, ***Van Niel*** hypothesized that plants split water as a source of hydrogen, releasing oxygen as a by-product. Neil's hypothesis was based on his investigations on photosynthesis in bacteria that make carbohydrate from carbon dioxide, but do not release oxygen.
- Neil's hypothesis was later confirmed by scientists during 1940s when first use of biological tracer (O^{18}) in biological research was made. Carbon dioxide and water containing heavy-oxygen isotopes O^{18} were prepared in the laboratory. Two groups of plants were made.

First Group

- Experimental green plants of first group were supplied with H_2O containing O^{18} and with CO_2 containing common oxygen O^{16}.
 These plants produced O^{18}.

$$\text{Group – 1 plants: } CO_2 + 2H_2O^{18} \longrightarrow CH_2O + H_2O + {}^{18}O_2$$

Second Group

- Plants in the second group were supplied with H_2O containing common oxygen O^{16} but with CO_2 containing O^{18}.
 These plants did not produce O^{18}.

$$\text{Group 2 Plants: } CO^{18}{}_2 + 2H_2O \longrightarrow CH_2O^{18} + H_2O^{18} + O_2$$

- These experiments showed that oxygen produced during photosynthesis comes from water.

ROLE OF CO_2 IN PHOTOSYNTHESIS

Source of CO_2

- Reduction of CO_2 is done during light-independent reactions of photosynthesis by using ATP and NADH (products of light-dependent reaction). Due to this, sugar is formed. This shows that photosynthesis is not possible in the absence of CO_2.
- About **10** ***percent*** of total photosynthesis is carried out by terrestrial plants, and the rest occurs in oceans, lakes and ponds.
- Aquatic photosynthetic organisms use dissolved CO_2, bicarbonates and soluble carbonates that are present in water as carbon source.
- Photosynthesis occurring on land utilizes atmospheric CO_2. Air contains **0.03-0.04** percent of CO_2.

CRITICAL THINKING

2. **The splitting of carbon dioxide to form oxygen gas and carbon compounds occurs during:**
 A. Photosynthesis
 B. Respiration
 C. Both photosynthesis and respiration
 D. Neither photosynthesis nor respiration

Passage of CO_2 to Enter in Plants

- Carbon dioxide enters the leaves through stomata and gets dissolved in the water absorbed by the cell walls of mesophyll cells. Stomata are found in a large number in a leaf. Their number is proportional to the amount of gas diffusing into the leaf. ***Stomata*** cover only **1-2%** of the leaf surface but they allow proportionally much more gas to diffuse.

Effect of Opening and Closing of Stomata

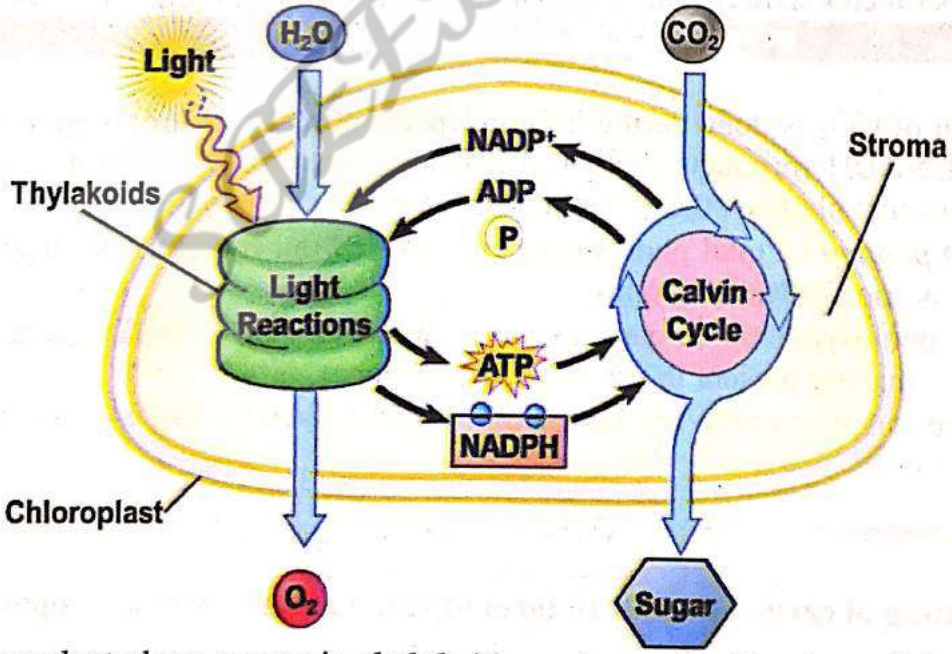
- The entry of CO_2 into the leaves depends upon the opening of ***stomata***.
- Stoma is an opening surrounded by ***guard cells***. Because of peculiar structure and changes in their shape, they regulate the opening and closing of stomata.
- Stomata are adjustable pores, which are;
- Open during daytime when CO_2 is required.
- Closed at night when photosynthesis stops.

MECHANISM OF PHOTOSYNTHESIS

- Photosynthesis is a 'redox process'.
- Overall equation of photosynthesis is:

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

- These reactions of photosynthesis consist of two parts i.e. light-dependent reactions and light-independent reactions.



- Light dependent phase occurs in ***thylakoid membrane***. In this phase, light energy is used to make ***ATP/assimilating power*** and ***NADPH/reducing power***; whereas water and oxygen are supposed to be input and out respectively.
- Light independent phase occurs in ***stroma of chloroplast*** and actually requires the products of light reactions i.e., ATP and NADPH.

LIGHT DEPENDENT REACTIONS

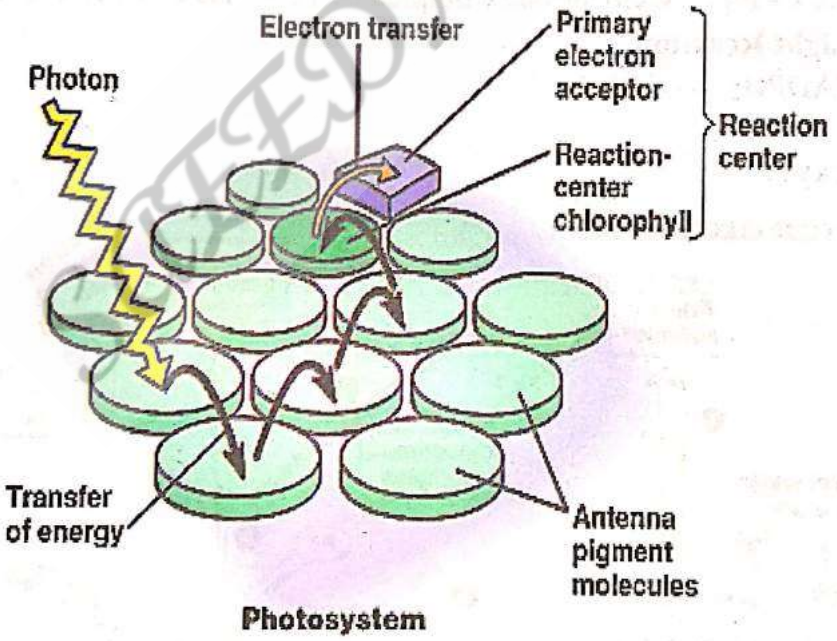
- Such types of reactions, which require light and constitute that phase of photosynthetic reaction during which light energy is absorbed by chlorophyll and other photosynthetic pigments and is converted into chemical energy, are called light reactions.
- As a result of this energy conversion, reducing and assimilating powers in the form of $NADPH_2$ ($NADPH + H^+$) and ATP are formed. Both temporarily store energy and carry along with H^+ to the light independent reactions.

Photosystems

- Photosynthetic pigments are organized into clusters called ***photosystems***.
- Photosystem are meant for efficient absorption and utilization of solar energy and are ***located on thylakoid membranes***.
- Each photosystem consists of two parts:

(i) The peripheral part of photosystem is called ***antenna complex*** which consists of many chlorophyll 'a', 'b' and carotenoids, which channelize energy to reaction centre.

(ii) The central part of the photosystem is called as ***reaction centre*** and is constituted by chlorophyll 'a' along with primary electron acceptor and associated electron carriers of electron transport system. Electron transport system plays role in generation of ATP by chemiosmosis.



Types of Photosystem

- There are two photosystems; photosystem-I and photosystem-II. These are named so in order of their discovery, and not for the order in which they occur in the thylakoid membrane.
- ***PS I*** have chlorophyll a molecule in reaction centre which absorbs maximum light of 700 nm, also called as P_{700}.
- ***PS II*** has a form of chlorophyll a molecule in reaction centre which absorbs maximum light of 680 nm, also called as P_{680}.

Non-Cyclic Photophosphorylation

Introduction

- It is predominant type of electron transport. In this process, both photosystems are utilized and two electrons transport chains are involved.
- Formation of ATP during non-cyclic electron flow is called non-cyclic photophosphorylation.
- Non-cyclic phosphorylation is also called ***Z-scheme,*** due to flow of electrons in Z-shape.

Mechanism

- Important steps of non-cyclic photophosphorylation are:

(i) Photo-excitation of electrons.
(ii) Photolysis of water.
(iii) Electron transport and formation of ATP through chemiosmosis.
(iv) Formation of $NADPH_2$.

CRITICAL CONCEPT!

Redox Reactions in Living Systems:
In ETC, all molecules oxidize and reduce in the same manner and sequence. This oxidation and reduction produce energy that can be utilized for the formation of ATP in chemiosmosis.

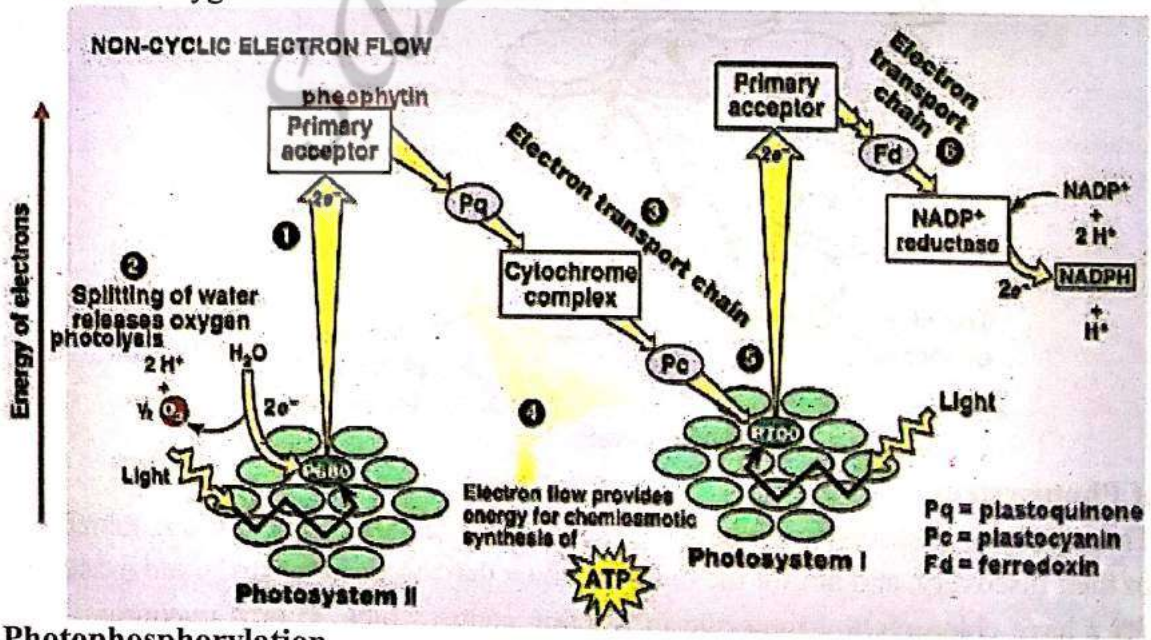
- The oxygen produced during photolysis is the main source of replenishment of atmospheric oxygen.
- Plastoquinone (Pq), Cytochromes and Ferredoxin (Fd)are iron containing electron carriers while Plastocyanin (Pc) is copper containing electron carrier.
- One photon excites one electron.

Passage of Electrons

PS II → PEA → Pq → Cytochrome Complex → Pc → PS I → PEA → Fd → $NADP^+$

End Products of Light Reaction

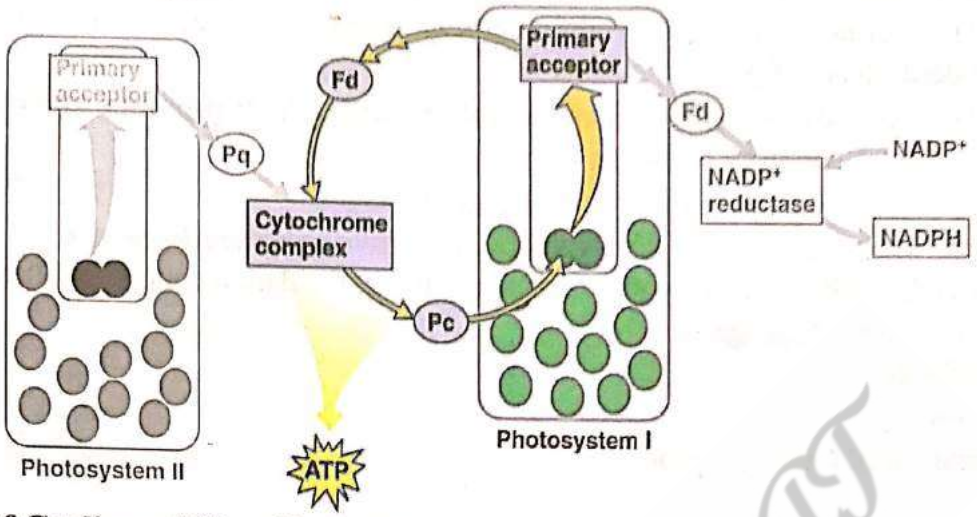
- NADPH/ $NADPH_2$
- ATP
- Molecular oxygen



Cyclic Photophosphorylation

- It occurs at that time when chloroplast run low on ATP for Calvin cycle, the cycle slows down and NADPH accumulate in chloroplast.

- This rise in NADPH may stimulate a temporary shift from non-cyclic to cyclic electron flow until ATP supply meets the demand.
- It is less common type.

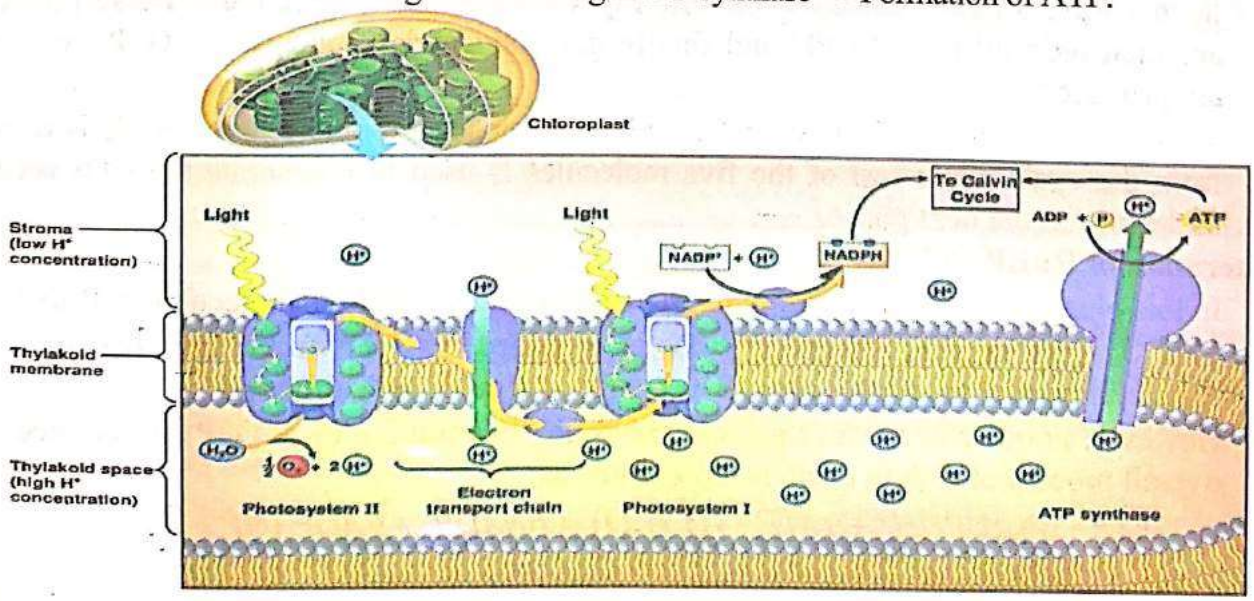


Comparison of Cyclic and Non-Cyclic Phosphorylation

Non-Cyclic Photophosphorylation	Cyclic Photophosphorylation
Electrons are not reused.	Electrons are reused.
It involves both PS I and II.	It involves only PS I.
It is long pathway.	It is short circuit.
It is normal process.	It occurs when ATP is less and NADPH is more.
It generates both ATP and NADPH.	It generates only ATP.
H_2O splits.	H_2O does not split
Oxygen is released.	Oxygen is not released.

Chemiosmosis

- In both cyclic and non-cyclic photophosphorylation, the mechanism for ATP synthesis is chemiosmosis.
- It is the process that uses membranes to couple redox reactions for ATP production.
- Flow of Electrons through ETC → Release of Energy → Pumping of protons (H^+) across thylakoid membrane → Transformation into potential energy stored in form of H^+ gradient → Movement of H^+ down the gradient through ATP synthase → Formation of ATP.



LIGHT INDEPENDENT REACTIONS

- Those reactions which do not require light directly and can occur in the presence or absence of light provided that assimilatory power in the form of ATP and reducing power $NADPH_2$, produced during the light reactions, is called dark reactions and constitute light independent phase of photosynthesis.
- $NADPH_2$ provides energized electron and H^+ while ATP provides chemical energy for the synthesis of sugar by reducing CO_2.
- These reactions take place in stroma of chloroplast.
- The cyclic series of reactions, catalyzed by respective enzymes, by which the carbon is fixed and reduced, resulting in the synthesis of sugar during the dark reaction, is called ***Calvin Cycle.***
- It is divided into three steps:

(i) Carbon fixation
(ii) Reduction
(iii) Regeneration of CO_2 acceptor.

CO_2 Fixation

- Carbon fixation refers to the initial incorporation of CO_2 into organic material/***RuBP***. It is generally referred as CO_2 acceptor because it is capable of combining with CO_2.
- CO_2 fixation is dependent on ribulose bisphosphate carboxylase (***RuBisCO***).
- Rubisco is most abundant protein in chloroplast and on earth.
- Three CO_2 molecules are required to synthesize one molecule of carbohydrate, a triose.
- Three intermediate molecules of six carbons are formed during this reaction. These molecules are unstable and exist for such a short time that they cannot be isolated.
- Each six-carbon containing molecule breaks down to form two molecules of 3-phosphoglycerate (3-PGA), a phosphorous containing compound with three carbon atoms.
- As the first stable compound in Calvin cycle is a three-carbon compound that is why Calvin cycle is also called as C3 pathway.

Reduction

- In this phase, six molecules of 3-PGA react with six ATP molecules, a phosphate from each ATP is transferred to each 3-PGA.
- In this way, 3-PGA molecule converted into 1,3-bisphosphoglycerate. These molecules are then reduced by NADPH and finally glycereldehyde 3-phosphtae (G3P) molecules are produced.
- Total six molecules of G3P are produced in this phase but only one molecule is released from the cycle while rest of the five molecules is used to regenerate the CO_2 acceptor molecules in the next phase.

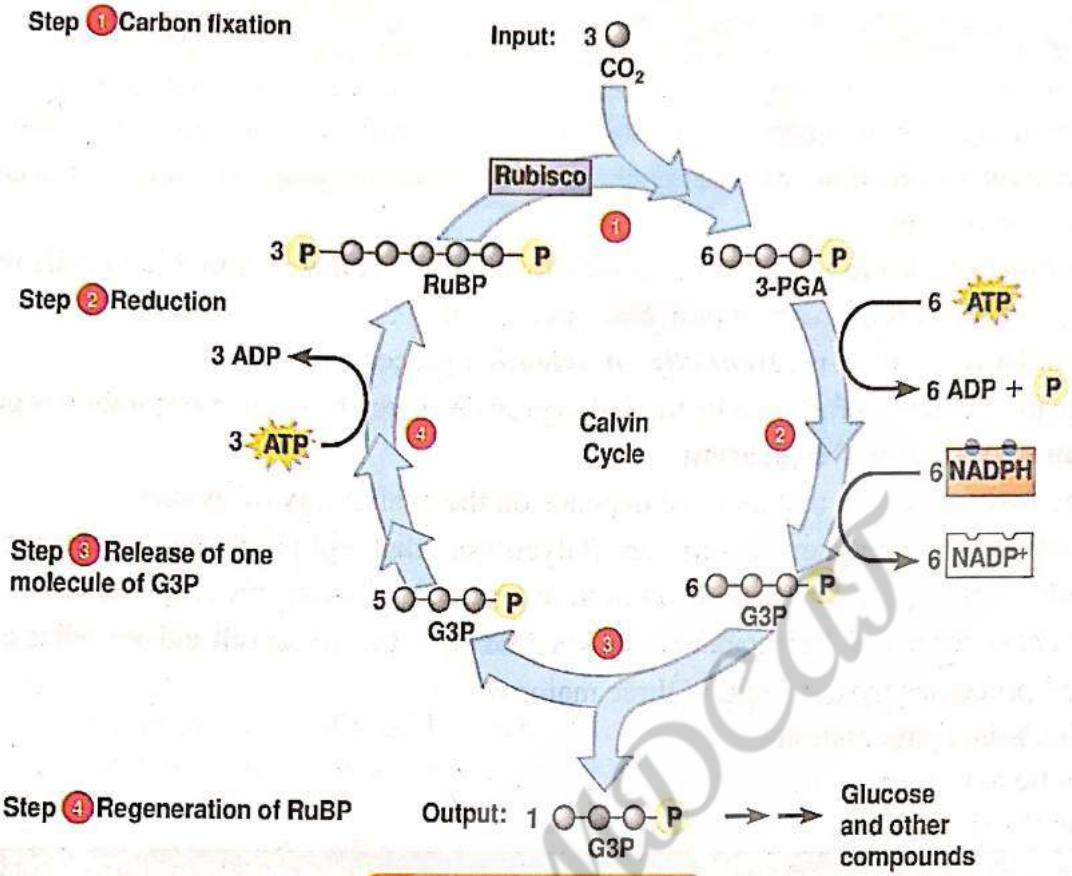
Regeneration of RuBP

- In this phase, five molecules of G3P are used to regenerate three molecules of RuBP.
- This conversion requires energy that is provided by ATP from light reactions. For regeneration of 3 molecules of RuBP, 3 ATP molecules are consumed.
- However, in order to produce glucose molecule, two molecules of G3P are required. The overall process of Calvin cycle is represented as:

$$3CO_2 + 6NADPHH^+ + 9ATP \rightarrow (CH_2O)_3 + 6NADP^+ + 9ADP + 9P_i + 3H_2O$$

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CRITICAL THINKING

3. Calvin cycle is also known as dark reactions. In cyclic pathway using products of light reaction, carbohydrate is produced. How many molecules of ATP and NADPH are used in synthesis of a polymer having 20 glucose molecules?

A. 360 ATP and 180 NADPH
B. 360 ATP and 240 NADPH
C. 180 ATP and 360 NADPH
D. 180 ATP and 120 NADPH

Comparison of Light and Dark Reactions

Features	Light Reactions	Dark Reactions
Site	Grana of chloroplast.	Stroma of chloroplast.
Requirement of Light	Yes	No
Products	O_2, ATP and $NADPH_2$ are the end products.	In Calvin cycle, ATP and $NADPH_2$ are used to prepare carbohydrates (G3P)
Reactant	Water is used	CO_2 is used

CRITICAL THINKING

4. Assume a thylakoid is somehow punctured so that the interior of the thylakoid is no longer separated from the stroma. This damage will have the most direct effect on which of the following processes?

A. The splitting of water
B. Absorption of light energy by chlorophyll
C. The synthesis of ATP
D. The reduction of $NADP^+$

CELLULAR RESPIRATION

- Respiration is the universal process by which organisms breakdown complex compounds containing carbon in a way that allows the cells to harvest a maximum of usable energy.
- ***External respiration*** involves exchange of respiratory gases between the organism and its environment.
- ***Cellular respiration*** is the process by which energy is made available to cells in a step by step breakdown of C-chain molecules in the cell.
- Cellular respiration is ***essentially an oxidation*** process.
- The most common fuel used by the cell to provide energy by cellular respiration is glucose.

Aerobic and Anaerobic Respiration

- The way glucose is metabolized depends on the availability of oxygen.
- First step of cellular respiration (Glycolysis that splits glucose molecule into two molecules of pyruvic acid) is common in aerobic and anaerobic respiration.
- The next step in cellular respiration varies depending on the type of cell and prevailing conditions.
- Cell processes pyruvic acid in three major ways:

(i) Alcoholic fermentation
(ii) Lactic acid fermentation
(iii) Aerobic respiration

Feature	Aerobic Respiration	Anaerobic Respiration
Involvement of Oxygen	Occurs in presence of O_2	Occurs in absence of O_2
Reactants	Glucose & O_2	Glucose
Glucose Breakdown	Involves complete breakdown of glucose	Involves incomplete breakdown of glucose
End Products	CO_2, H_2O and energy	Lactic acid or Ethyl alcohol & CO_2
ATP Formed	Total: 40 ATP Net: 36 or 38 ATP	Total: 4 ATP Net: 2 ATP
Location in Eukaryotic Cell	Mitochondria	Cytoplasm

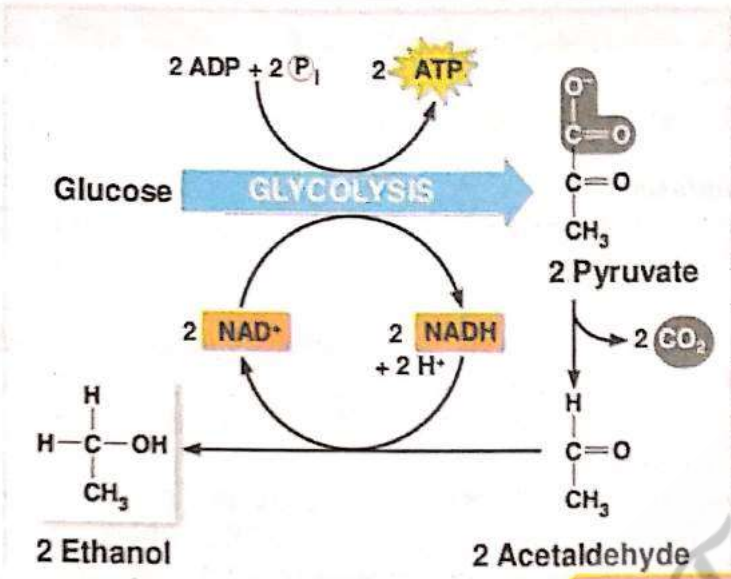
MECHANISM OF ANAEROBIC RESPIRATION

- An aerobic respiration is incomplete breakdown of glucose in the absence of oxygen. It is also known as ***fermentation***. There are two pathways of anaerobic respiration depending upon the nature of final products.

(i) Alcoholic Fermentation

- Alcoholic fermentation is found in yeast. It consists of glycolysis followed by the decarboxylation of pyruvate to acetaldehyde and then reduction of acetaldehyde by NADH to ethyl alcohol.
- This pathway operates anaerobically because after NADH transfers its electron to acetaldehyde, it is 'free' to return and pick up more electrons during the earlier reactions of glycolysis.

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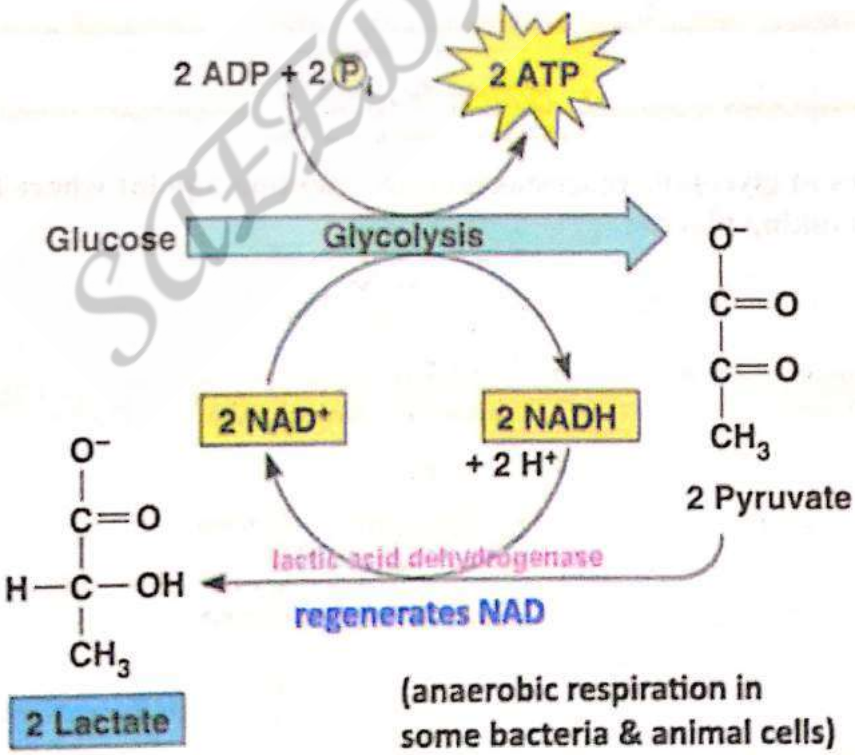


(ii) Lactic Acid Fermentation

- It consists of glycolysis followed by the reduction of pyruvate by NADH to lactic acid.
- It occurs in muscle cells of humans and other animals during strenuous physical activities when oxygen supply is exhausted. The accumulation of lactic acid causes muscle fatigue and muscles become unable to contract.

CRITICAL CONCEPT!

Cori Cycle:
Lactic acid produced in skeletal muscle is converted to glucose in the liver, and transported back to skeletal muscle.



MECHANISM OF AEROBIC RESPIRATION

Aerobic respiration may be subdivided into four stages:

(i) Glycolysis
(ii) Pyruvic acid oxidation
(iii) Krebs cycle or citric acid cycle or tricarboxylic acid cycle

GLYCOLYSIS

- Glycolysis is the breakdown of glucose or similar hexose sugar into two molecules of pyruvic acid through a series of enzymatic reactions releasing some molecules of ATP and NADH.
- It occurs in ***cytoplasm***.
- It takes place in the absence (***Anaerobic***) or in the presence of O_2 (***Aerobic***).
- Enzymes, ATP, and Coenzyme NAD^+ are essential for glycolysis.

Phases of Glycolysis

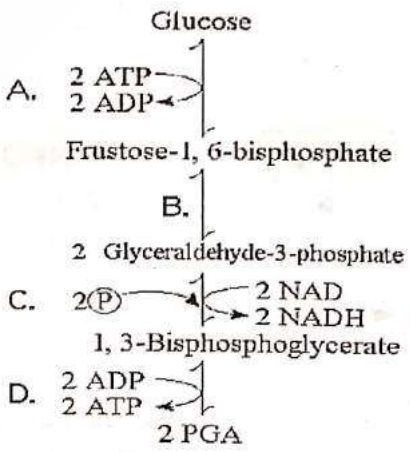
- There are two phases of glycolysis i.e. ***preparatory phase*** and ***oxidative phase***.
- ***Preparatory phase*** is an investment phase in which two ATP molecules are consumed. Its end products are two molecules of G3P, and one molecule of DHAP which will also isomerized to form G3P.
- ***Oxidative or pay off phase*** is characterized by the ATP production through ***substrate level phosphorylation***. It also produces NADH which upon further oxidation in respiratory electron transport chain yields more ATP molecules.

CRITICAL THINKING

5. **Which of the following conversions shows the activity of Kinase?**
 A. Phosphoenol pyruvate to Pyruvate
 B. 1, 3-Bisphosphoglycerate to 3-Phosphoglycerate
 C. Fructose 6-phosphate to Fructose 1, 6 bisphosphate
 D. α-Ketoglutarate to Succinate

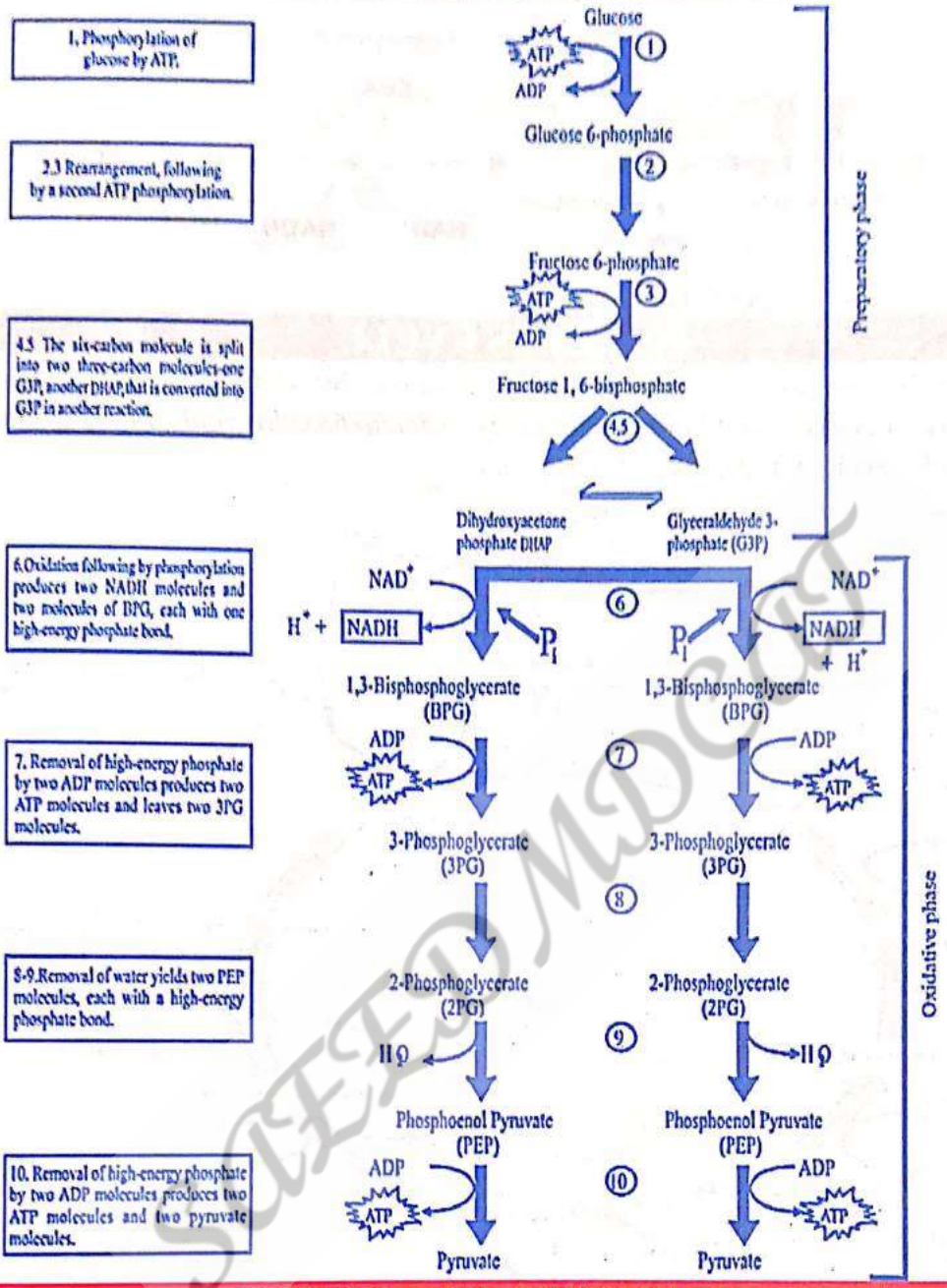
CRITICAL THINKING

6. **A summary of glycolytic reactions is given. Mention a point where redox reaction is taking place.**



End Products

- Total consumption of ATP during glycolysis is 2ATP molecules.
- Total production of ATP during glycolysis is 4ATP molecules.
- Net production of energy during glycolysis is 2ATP molecules.



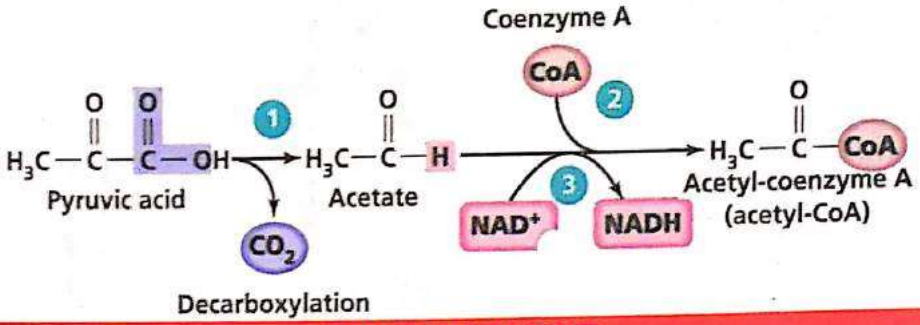
PYRUVIC ACID OXIDATION

- Because pyruvate is a charged molecule, it must enter the mitochondrion via active transport with the help of transport protein called ***pyruvate translocase***.
- On entering the mitochondria, pyruvate molecules do not directly participate in Krebs cycle but they undergo an intermediate phase, called ***oxidation of pyruvate*** or ***link reaction***. The events of link reaction are shown in the following diagram.

CRITICAL CONCEPT!

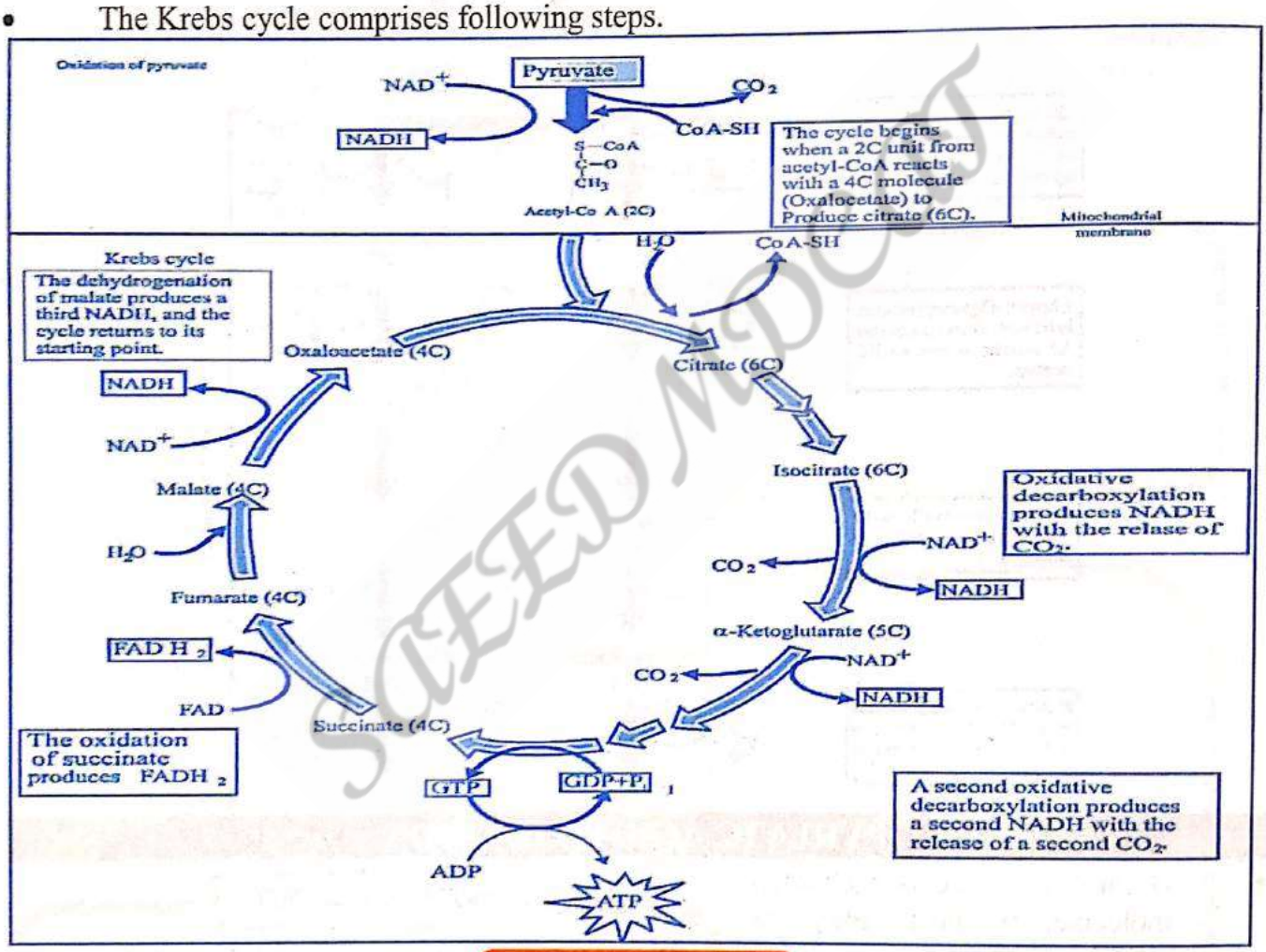
Relationship b/w Pyruvic Acid and Lactic Acid:

Pyruvic acid is less dangerous than the Lactic acid but it is converted into lactic acid during anaerobic conditions. This lactic acid fermentation gives NAD^+ that works in the glycolysis to maintain minimum supply of energy in anaerobic condition i.e., 2 ATPs.



KREBS CYCLE

- This cyclic metabolic reaction was discovered by British Scientist Sir Hans Krebs, therefore, it is also called ***citric acid cycle*** or ***tricarboxylic acid (TCA) cycle.***
- The Krebs cycle comprises following steps.



CRITICAL THINKING

7. **All of the following involve reduction of coenzymes except:**
 A. Succinate to Fumarate
 B. Isocitrate to α-Ketoglutarate
 C. Pyruvate to acetyl Co-A
 D. Fumarate to Malate
8. **TCA cycle involves inter-conversion of carbohydrate molecules. Which of the following process takes place only once during the completion of one cycle?**
 A. Isomerism
 B. Reduction
 C. Oxidation
 D. Decarboxylation

- One Krebs cycle yields one molecule of ATP, three molecules of NADH and one molecule of $FADH_2$.

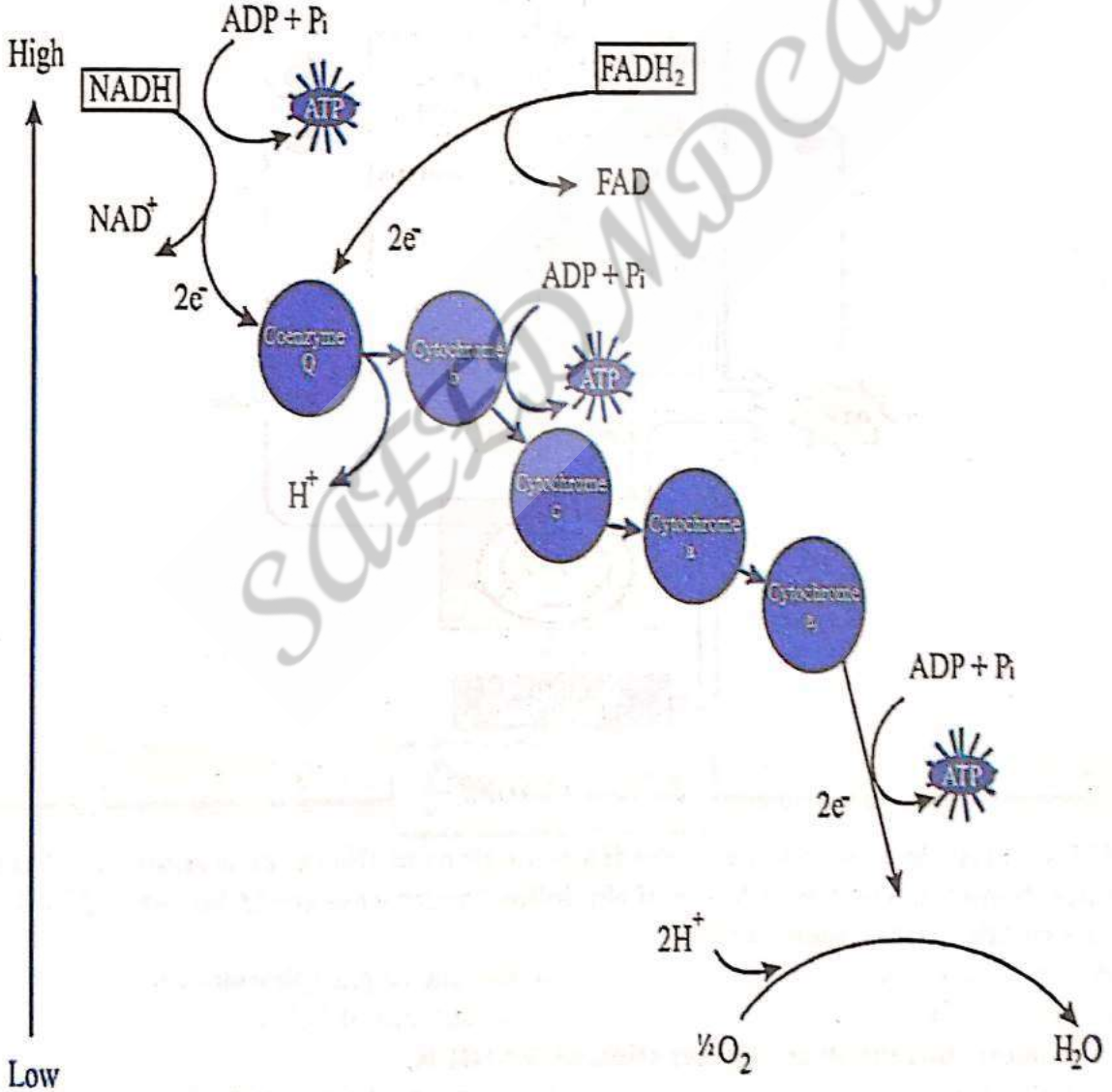
Respiratory Chain/Electron Transport Chain

- A system where electrons are transported in a series of oxidation-reduction steps to react ultimately, with molecular oxygen is called ***electron transport system or respiratory chain.***

CRITICAL CONCEPT!

Energy Production in Living System:
In living systems, energy is being released in bits as per requirement of the body. This is being done to avoid the release of extra heat energy and denaturation of proteins including enzymes.

- Synthesis of ATP in the presence of O_2 is called ***oxidative phosphorylation.***
- During oxidative phosphorylation, 3 ATPs are formed from one NADH and two ATPs are formed from one $FADH_2$.
- Sequence of electron flow is as follows:



Oxidative Phosphorylation

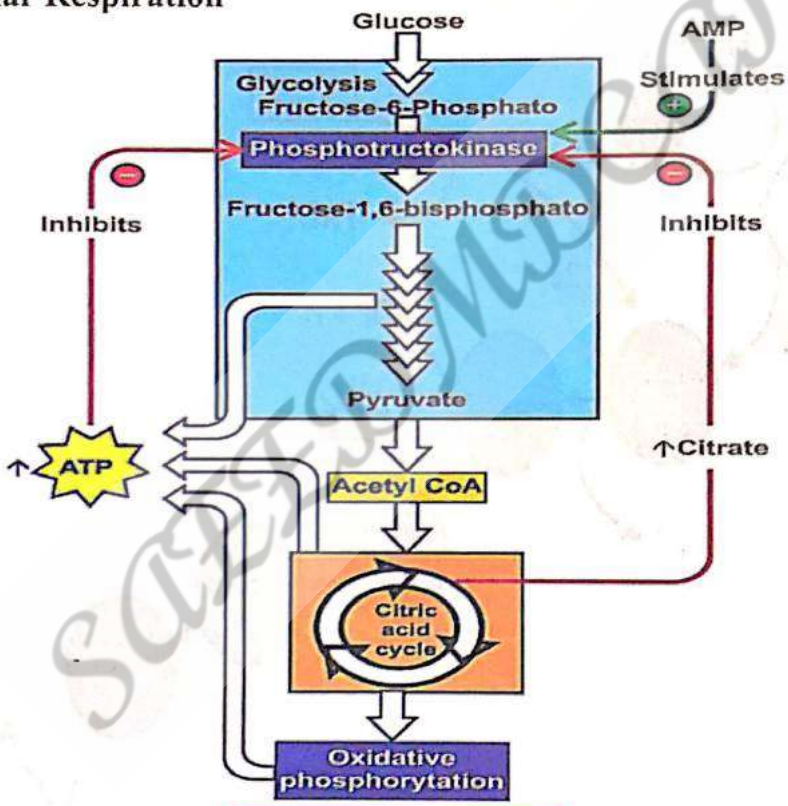
- Synthesis of ATP in the presence of oxygen is called oxidative phosphorylation.

- Oxidative phosphorylation is coupled with respiratory chain in the inner membrane of mitochondrion.
- As compared to photosynthesis, here pumping of protons (H^+) is across the inner membrane of mitochondrion folded into cristae, between matrix of mitochondrion and mitochondrion's inter-membrane space.

CRITICAL CONCEPT!

Chemiosmosis Site	Proton pumping	H^+ Diffusion
Chloroplast	Stroma to Lumen	Lumen to Stroma
Mitochondria	Matrix to inter-membrane space	Inter-membrane space to Matrix
Bacteria	Cytoplasm to periplasmic space	Periplasmic space to cytoplasm

Regulation of Cellular Respiration



CRITICAL THINKING

9. If it is possible to prepare vesicles from portions of the inner membrane of the mitochondria. Then which one of the following process could be carried on by this isolated inner membrane?

A. Citric acid cycle
B. Oxidative phosphorylation
C. Beta oxidation
D. Reduction of NAD^+

10. A process that involves regeneration of NADH is:

A. Glycolysis
B. Lactic acid fermentation
C. Oxidative phosphorylation
D. Alcoholic fermentation

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TOPIC-3 » BIOLOGICAL MOLECULES

COURSE CONTENT

- Introduction to Biological Molecules
- Importance of Water
- Carbohydrates
- Proteins
- Lipids
- Nucleic Acids (RNA)
- Conjugated Molecules

INTRODUCTION TO BIOLOGICAL MOLECULES

Biological Molecules in Protoplasm

Early biologists thought that the cell consists of a homogeneous jelly, which they called protoplasm. Today the word protoplasm if used at all is applied in a very general way.

Parts of Protoplasm

- The portion of protoplasm outside the nucleus is called cytoplasm.
- The corresponding material within the nucleus is termed as nucleoplasm.

Composition of Cytoplasm

- The cytoplasm is composed of several types of organelles and a fluid matrix, the cytosol (literally cell solution) in which the organelles reside. The cytosol is a watery solution of salts, sugars, amino acids, proteins fatty acids, nucleotides etc.

Sr. No.	Chemical Components	% Total Cell Weight	
		Bacterial Cell	Mammalian Cell
1.	Water	70	70
2.	Proteins	15	18
3.	Carbohydrates	3	4
4.	Lipids	2	3
5.	DNA	1	0.25
6.	RNA	6	1.1
7.	Organic molecules (enzymes, hormones, metabolites)	2	2
8.	Inorganic ions (Na^+, K^+, Mg^{+2}, Cl^-, SO_4^{-2} etc.)	1	1

IMPORTANCE OF WATER

Importance

- Water is the ***medium of life*** and is ***most abundant compound*** in all organisms.
- It varies from 65 to 89% in different organisms.
- Human tissues contain about 20% water in bone cells and 85% in brain.
- It acts as a ***lubricant against friction***, e.g., tears protect the surface of eye from the rubbing of eyelids.
- It acts as fluid cushion around organs that protect them from trauma.
- Biochemical reactions take place in the presence of water.
- It also takes part in many biochemical reactions such as ***hydrolysis*** of macromolecules.
- It is also used as a ***raw material*** in reactions like photosynthesis.

High Polarity:

- In case of water, the sharing of electrons between oxygen and hydrogen in not completely equal so the covalent bond is polar.
- A polar covalent bond is a chemical bond in which shared electrons are pulled closer to the more electronegative atom, making it partially negative and the other atom partially positive.
- Thus, in H_2O, the O_2 atom actually has a slight negative charge and each H_2 atom has a slight positive charge, even though H_2O as a whole is neutral. Because of its polar covalent bonds, water is polar molecule i.e., it has a slightly negative pole and two slightly positive poles.
- This is polarity of water molecules that makes it an excellent o universal solvent for polar substances.
- Ionic compounds or electrolytes can be easily dissolved in water, non-polar substances having charged groups in their molecules can also be dissolved in water.
- Such compounds when dissolved in water, dissociates into positive and negative ions and are in more favorable state to react with other molecules and ions. This is the reason why all chemical reactions in living beings occur in aqueous medium.

CRITICAL THINKING

1. **Hydrogen bonds are especially important for living organisms because:**
 A. Once formed, they never break
 B. They occur only inside of organisms
 C. They are strong and maintain physical stability of molecules
 D. They allow biological molecules to dissolved in water

High Specific Heat Capacity:

- Heat capacity can be defined as 'the amount of heat required for minimum increase ($1^{\circ}C$ or $1^{\circ}K$) in temperature of a substance. The specific heat capacity of water can be represented as number of calories required to raise the temperature of 1g of water upto $1^{\circ}C$.
- Water has relatively a very high heat capacity than any other substance due to its hydrogen bonding, because much of the heat absorbed by water is utilized in the breakdown of hydrogen bonding.
- Due to this high heat capacity, water works as ***temperature stabilizer or regulator*** for organisms in the hot environment and hence protects the living material against sudden thermal changes.

Heat of Vaporization:

- Amount of heat absorbed when 1g of water to change from liquid to gaseous state is called ***heat of vaporization***.
- Specific heat of vaporization of ***water is 574 Kcal/ kg***.
- Evaporation of only 2ml out of 1 liter of water lowers the temperature of remaining 998ml by $1^{\circ}C$.
- The advantage of high heat of vaporization of water is that it provides cooling effect to plants and animals.

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Hydrophobic Exclusion

- Hydrophobic exclusion can be defined as 'reduction of the contact area between water and hydrophobic substances which are placed in water'.
- For example, if few drops of oil is placed on the surface of water solution, the oil drops will tend to coalesce into a single group.
- Biologically, hydrophobic exclusion plays key role in ***maintaining the integrity of lipid bilayer membrane***.

Density of Water:

- Ice float on water. This is because ice is less dense than water. The reason is that ice has a giant structure and show maximum number of hydrogen bonding among water molecules; hence, they are arranged like a lattice.
- In freezing weather, ice forms on the surface of ponds and lakes forming an insulating layer above the water below. This provides a living environment for some organisms until the ice melts.

Cohesion and Adhesion Property of Water:

- ***Cohesion*** is the attraction among water molecules which enables them to stick together. Water flows freely due to cohesion.
- Water molecules also have attraction to polar surfaces. This attraction is called ***adhesion.***
- Both cohesion and adhesion are due to hydrogen bonds among water molecules. These properties enable it to circulate in living bodies and to act as ***transport medium***.

Ionization of Water

- $H_2O \rightleftharpoons H^+ + OH^-$ it is a reversible reaction.
- At 25°C, the concentration of each H^+ and OH^- ions in pure water is about $\mathbf{10^{-7}}$ **moles/lit**.
- H^+ and OH^- ions take part in many reactions that occur in cell.

CARBOHYDRATES

- Literal meaning "hydrated carbons".
- They are composed of C, H_2, and O_2. Mostly hydrogen and oxygen are found in same ratio as in water (2:1).
- Chemically they are defined as "polyhydroxy aldehydes or ketones or complex substances which on hydrolysis yield polyhydroxy aldehyde or ketone subunits."
- Their ***general formula*** is $C_x(H_2O)_y$ where 'x' is the whole number from three to many thousands whereas 'y' may be same or different whole number.
- Simple carbohydrates are the main ***source of energy*** in cell.
- Some carbohydrates are the main ***constituents of cell walls*** in plants and microorganisms.
- Examples are cellulose in wood, cotton and paper, starches present in cereals, root tubers, cane sugar and milk sugar.

CRITICAL THINKING

2. Glucose and hexanoic acid each contain six carbon atoms, but they have completely different properties. Glucose is used as a primary fuel by the cell while hexanoic acid is poisonous. Their differences must to be due to:

A. Monomers
B. Macromolecules
C. Functional groups
D. Quaternary structures

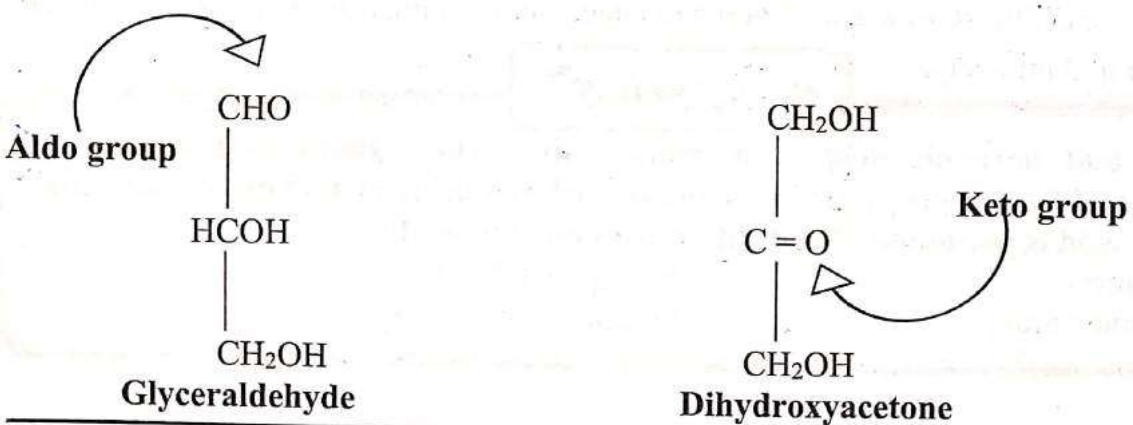
- Their main sources are green plants, which produce them by photosynthesis. Even all the other compounds of plants are synthesized from carbohydrates.
- Carbohydrates combine with proteins and lipids to form ***glycoprotein & glycolipids*** respectively. These compounds are collectively called glyco-conjugates.

Major Groups of Carbohydrates

Feature	Monosaccharides	Oligosaccharides	Polysaccharides
Common Name	Simple sugars	Complex sugars	Most complex sugars(Branched or unbranched)
No. of sugar units	One	Two – Ten	$10 \leq 1000$ or above
Taste	Sweet	Less sweet	Tasteless
Solubility in water	Easily soluble in water	Less soluble in water	Sparingly soluble in water
Hydrolysis	Cannot be hydrolyzed	Can be hydrolyzed	Can be hydrolyzed
General Formula	$(CH_2O)_n$/ $C_nH_{2n}O_n$/ $C_n(H_2O)_n$	$C_n(H_2O)_{n-1}$ (for disaccharides)	$C_x(H_2O)_y$
Classification	On the bases of number of carbon atoms e.g. trioses (3C), tetroses (4C), pentoses (5C) etc. • On base of functional group e.g. aldo and keto sugars.	On the bases of monosaccharides released during hydrolysis e.g. disaccharides, trisaccharides etc.	On the bases of structural complexity & relation e.g. starch, glycogen, cellulose, dextrin, agar, pectin and chitin.

Monosaccharides

- Monosaccharides are true carbohydrates which are either polyhydroxy aldehydes or polyhydroxy ketones.
- In nature, monosaccharides with ***3 – 7 carbon atoms*** are found.
- All carbon atoms except one have hydroxyl group. This exception is carbon of aldehyde or ketone group.



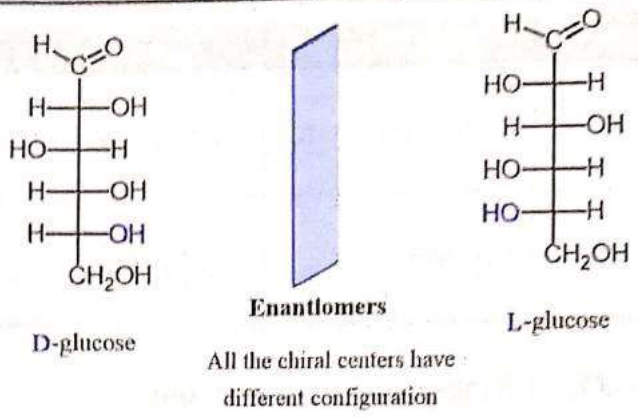
Atoms	Type	Formula	Aldo Form	Keto Form	Role
3 C	Trioses	$C_3H_6O_3$	Glyceraldehyde	Dihydroxyacetone	Intermediates in photosynthesis & respiration
4 C	Tetroses	$C_4H_8O_4$	Erythrose	Erythrulose	Intermediates in photosynthesis in bacteria
5 C	Pentoses	$C_5H_{10}O_5$	Ribose	Ribulose	Ribose is found in RNA while Ribulose is found in Calvin cycle
6 C	Hexoses	$C_6H_{12}O_6$	Glucose	Fructose	Energy source, Polysaccharide formation
7 C	Heptose	$C_7H_{14}O_7$	Glucoheptose	Sedoheptulose	Intermediates in photosynthesis in bacteria

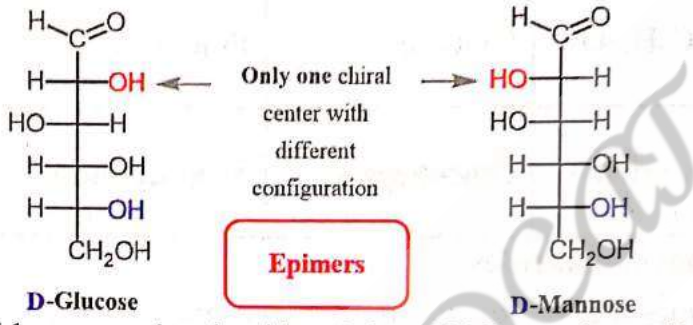
Ring Structure of Monosaccharides

- Monosaccharides are usually found in open chain structure in crystalline form but when they are dissolved in water, most of them (e.g. pentoses and hexoses) are converted into ring structure.
- Two types of ring structures are formed e.g. ***furanose*** is a five membered ring in which one oxygen atom and four carbon atoms are found, oxygen atom is linked with C_1 and C_4. All pentoses and ketohexoses are converted into furanose ring. ***Pyranose*** is a six membered ring in one oxygen atom and five carbon atoms are found, and oxygen atom is linked with C_1 and C_5. Only aldohexoses are converted into pyranose ring.

Sterioisomerism in Monosaccharides

- Those isomers in which –H and –OH groups are arranged in different pattern to the asymmetric carbon atoms are called ***stereoisomers***.
- An ***asymmetric carbon*** atom is that which makes bonds with four different atoms/groups around it.
- In monosaccharides, the number of stereoisomers actually depends upon the number of asymmetric carbon atoms in its structure and can be calculated by the formula 2^n, where 'n' is the number of asymmetric carbon atoms.
- ***Enantiomers*** are non-superimposable mirror images of one another. An example of an enantiomer is the 'D' and 'L' isomers of glucose.
- ***Diastereoisomers*** are those which have different arrangement of –H and –OH group at more than one asymmetrical carbon atoms. Unlike enantiomers, these are not mirror images.
- ***Epimers*** have different arrangement of –H and –OH groups at only one asymmetric carbon atom.

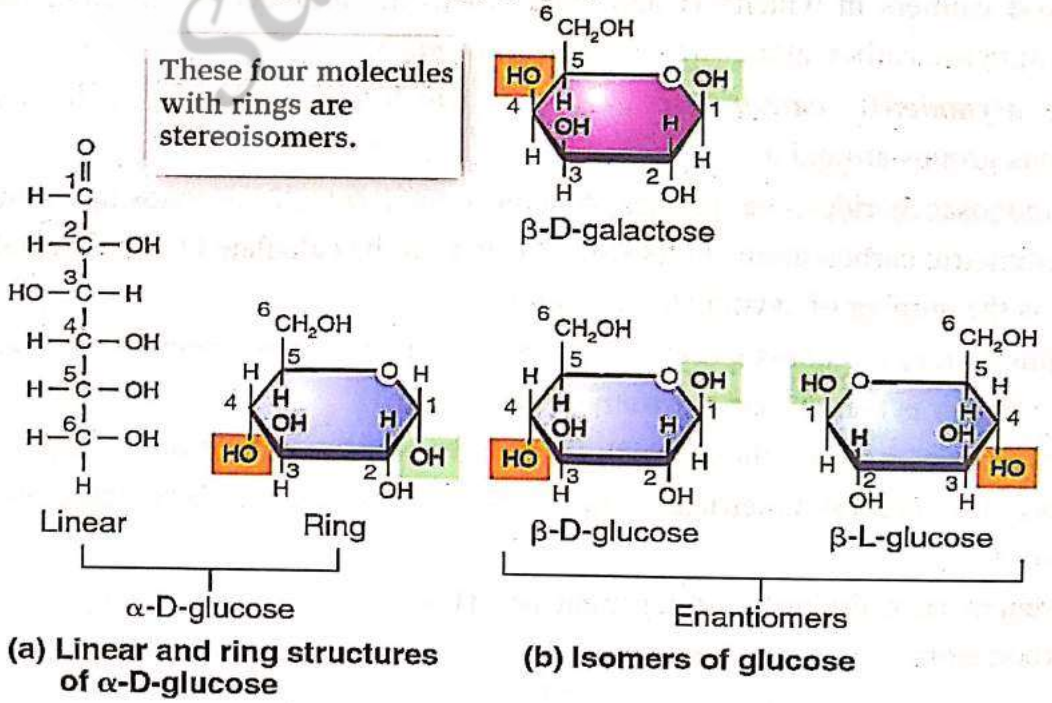




- Each pentose and hexose exists in either 'α' or 'β' forms depending upon position of H^+ and OH^- groups at C_1. If OH^- group is found downward at C_1, it is called 'α' sugar and if OH^- group is present upward on C_1 then it is known as 'β' sugar.

Glucose

- It is naturally produced in green plants which take CO_2 from air and H_2O from soil to synthesize glucose.
- Synthesis of ***10g of glucose*** requires ***717.6 Kcal*** of solar energy, which in turn is stored in glucose molecule and becomes available in all organisms when it is oxidized in the body.
- Our ***blood contains 0.08%*** glucose.
- Starch, cellulose, and glycogen yield glucose on complete hydrolysis.
- In free form, glucose is present in figs, grapes, and dates.

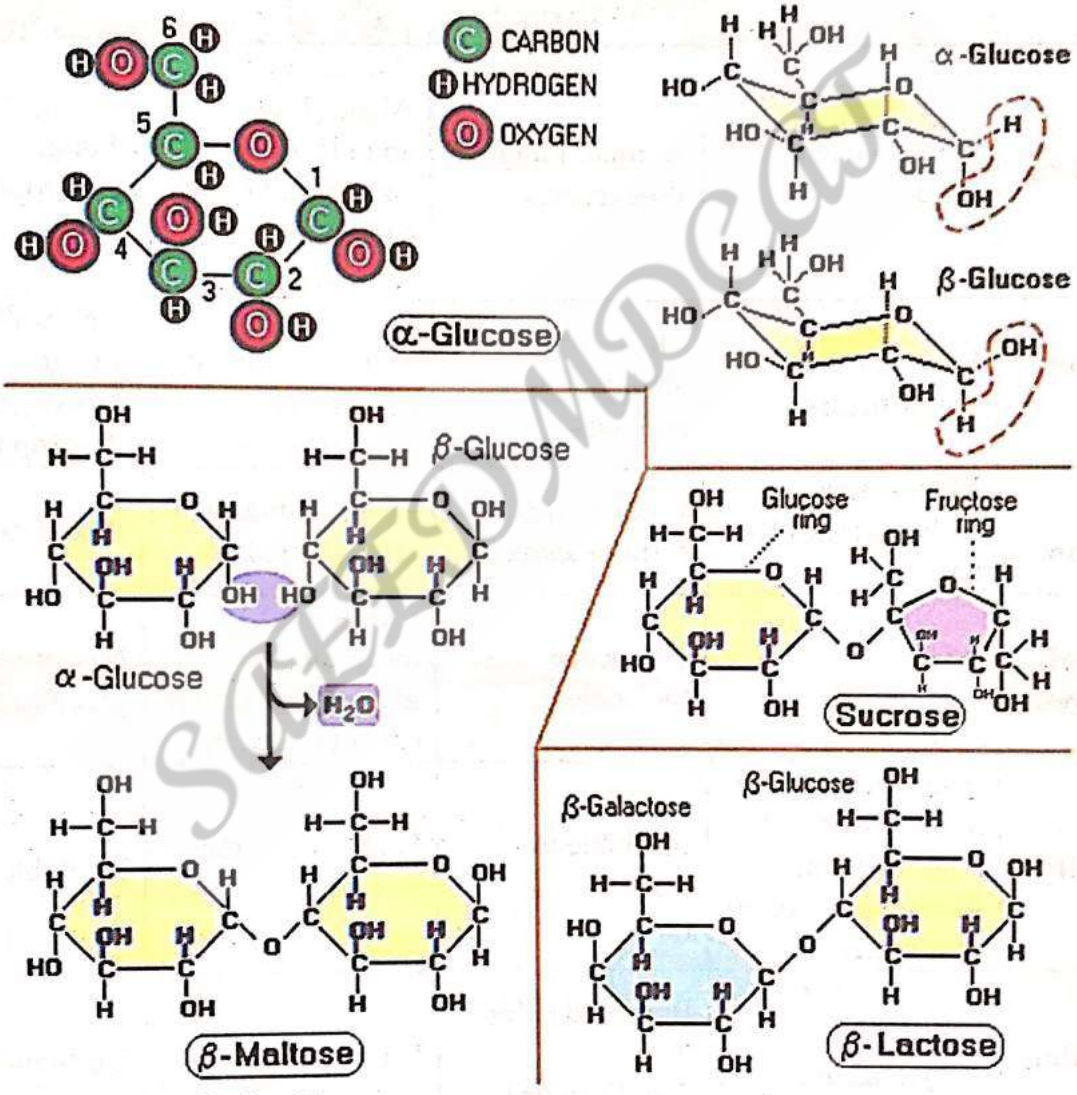


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Oligosaccharides

- Those oligosaccharides which yield two monosaccharides on hydrolysis are called ***disaccharides*** and those yielding three are called ***trisaccharides.***
- The covalent bond formed between two monosaccharides is called **glycosidic bond.**
- ***Maltose, sucrose,*** and ***lactose*** all are disaccharides. Their general formula is $C_{12}H_{22}O_{11}$.

Disaccharide	Source and Common Name	Monomers	Glycosidic Bond
Maltose	Candies, Barley, Sweet potatoes, Fruits (Malt Sugar)	Glucose + Glucose	1,4-glycosidic bond
Sucrose	Sugar Cane (Cane Sugar)	Glucose + Fructose	1,2-gycosidic bond
Lactose	Milk (Milk Sugar)	Galactose +Glucose	1,4-glycosidic bond



Reducing and Non-Reducing Sugars

- Sugars which give positive result on ***Benedict or Fehling tests*** are called reducing sugars. These act as reducing agents. They have free aldehyde or free ketone group. All monosaccharides, lactose and maltose are reducing sugars. Ketoses must first tautomerize to aldoses before they act as reducing sugars.
- ***Sucrose*** is an example of non-reducing sugar.
- ***Polysaccharides*** are also non-reducing sugars.

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Polysaccharides

- They are formed by several monosaccharide units linked together by glycosidic bonds.
- They act as structural components, food and energy stores.
- The polysaccharides which are composed by the condensation of only one kind of monosaccharides are called ***homo-polysaccharides*** e.g. starch, glycogen, cellulose, chitin (N_2-containing polysaccharide); whereas the polysaccharides which are composed by condensation of different kind of monosaccharides are called ***hetero-polysacchrides*** e.g. agar, pectin, peptidoglycan.

Classes of Polysaccharides

Feature	Starch	Glycogen (Animal Starch)	Cellulose	Chitin
Organism	Plants, Green Algae	Animal, Fungi, Prokaryotes	Plants, Green Algae (Most abundant carbohydrate). Cotton is pure form of cellulose.	Fungi, Arthropods
Location	Fruits, grains, seeds, tubers.	Most of cells but abundant in liver and muscles.	Main constituent of cell walls.	Cell wall in Fungi, Exoskeleton of Arthropods
Main Function	Main source of carbohydrates for animals.	Chief storage form in animals.	Main constituent of cell wall of plants.	Protection
Result of Hydrolysis	α-Glucose molecules	α-Glucose molecules	β-Glucose molecules (α-amylase in our gut cannot digest it)	N-acetyl β-glucosamine
Solubility	Amylose: Soluble in hot water Amylopectin: Insoluble in hot or cold water	Insoluble in water	Highly insoluble in water	Insoluble in water
Branching	Amylose: Un-branched Amylopectin: Branched	Branched (More than Amylopectin)	Un-branched	Un-branched
Glycosidic Linkage	Amylose: α–1, 4 Amylopectin: $\alpha-1,4$ & $\alpha-1,6$	$\alpha-1,4$ & $\alpha-1,6$	$\beta-1,4$	$\beta-1,4$
Iodine Test	Blue colour with iodine test	Red colour with iodine test	No colour change on iodine test	No colour change on iodine test

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Tests for Carbohydrates

- Benedict or Fehling test to detect reducing and non-reducing sugars.
- Iodine test is used to detect different types of polysaccharides.

CRITICAL THINKING?

3. **The enzyme called pancreatic amylase is a protein whose job is to attack on starch molecules in food and help break them down to maltose. Amylase cannot break down cellulose. Why not?**
 A. Cellulose molecules are too much large
 B. Starch is made of glucose, while cellulose is made of other sugars
 C. Cellulose is like a fat, not a carbohydrate like starch
 D. Monomers in cellulose bond together differently than in starch
4. **Carbohydrates are commonly found as starch in plant storage structures. Which of the following five properties (1-5) of starch make it useful as a storage material?**
 1. **Easily translocated**
 2. **Chemically non-reactive**
 3. **Easily digested by animals**
 4. **Osmotically inactive**
 5. **Synthesized during photosynthesis**

 A.1 and 5 only B. 2 and 4 only
 C. 2 and 3 only D. 1, 3 and 5 only
5. **It gives red color with iodine:**
 A. Storage homo-polymer with no branching
 B. Storage homo-polymer with branching
 C. Structural hetero-polymer with no branching
 D. Structural homo-polymer with no branching

PROTEINS

- They are the ***most abundant organic compounds*** found in cells and comprising over 50% of their total dry weight.
- Proteins are polymers of amino acids, the compounds containing ***C, N_2, O_2, and H_2*** and few amino acids contains S.
- Chemically, proteins can be defined as 'polymers of amino acids or polypeptides chains'. A protein may consist of a single or more than one polypeptide.

Example	Major Functions
Building Structures	Proteins are involved in building many structures e.g. collagen, elastin, keratin and histones.
Enzymes	Catalyze chemical reactions and control whole metabolism of cell.
Hormones	Regulate metabolic processes.
Transport Proteins	Carrier protein that transports O_2 (Hemoglobin), lipids, metal ions etc.
Antibodies	Defend the body against pathogenic attack.
Clotting Proteins	Prevent loss of blood after injury.
Mitotic Apparatus	Helps in movement of chromosomes during anaphase of cell division.

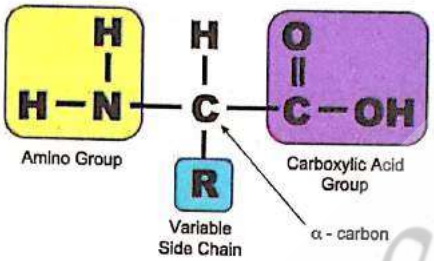
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Amino Acids

- Amino acids are the building blocks of proteins. About ***170 amino acids*** have been found in cells and tissues.
- Out of 170 types only ***25 are constituents of proteins.***
- Most of the proteins are, however, ***made of 20 types of amino acids.***

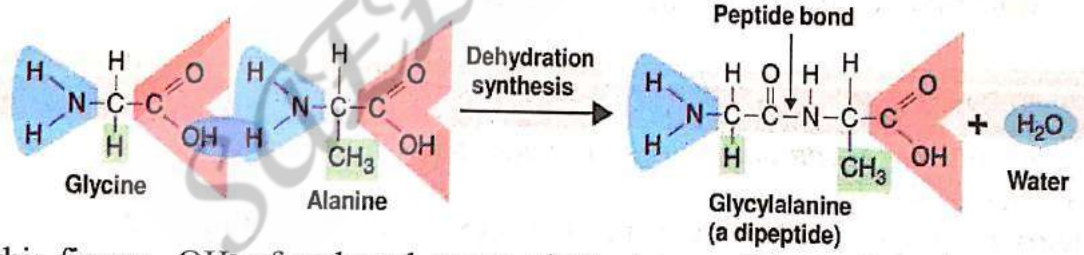
Basic Structure of Amino Acid

- An amino acid is an organic compound contains a central carbon atom, called ***alpha carbon***. To this, a hydrogen atom, an amino group ($-NH_2$), a carboxylic group (-COOH) and a variable group known as R-group.
- The R-group has a different structure in each of 20 biologically important amino acids and determines their individual chemical properties.



Peptide Bond Formation

- Dipeptides, oligopeptides and polypeptides are formed by the ***dehydration condensation*** of amino acids on the ribosomes under the instructions of mRNA which takes these instructions from DNA.
- Amino acids link together to form a polypeptide molecule.
- Two amino acids combine together via a peptide bond to form a dipeptide, e.g., Glycine and Alanine chemically interact with each other to form **glycylalanine**. Similarly, tri, tetra and pentapeptides can be formed. Naturally, this dehydration condensation reaction occurs during translation of mRNA.

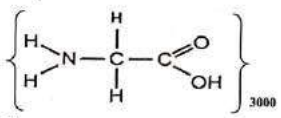


- In this figure, $-OH^-$ of carboxyl group of Glycine combines with H^+ of amino group of Alanine releasing water molecule and forming C-N link called ***peptide bond***.

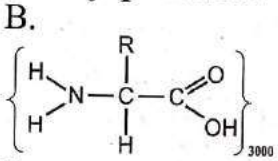
CRITICAL THINKING

6. Only one of the followings is technically possible:

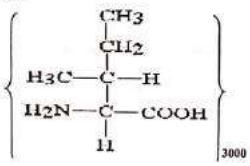
A.



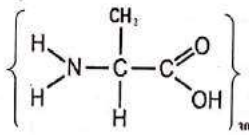
B.



C.



D.



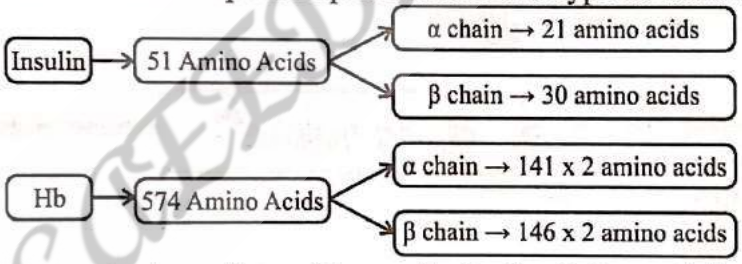
Structure of Proteins

There are four levels of organization of protein molecules.

Feature	Primary	Secondary	Tertiary	Quaternary
Information	Number and sequence of amino acids in protein molecule.	Structural conformation (form or shape) e.g. coil or helix	Bending and folding of polypeptide chain and forming regular 3-D globular shape.	Aggregation and held together by hydrophobic interactions.
Bonds	Peptide bond	Hydrogen	Ionic, Hydrogen, Disulphide bridges	Hydrogen, Ionic bonds, Hydrophobic interactions
Example	Insulin	Alpha helix (α-helix), β-pleated sheet	Human myoglobin	Hemoglobin

Primary Structure

- ***F. Sanger*** was the first scientist who determined the sequence of amino acids in a protein molecule.
- The sequence of amino acids in a protein molecule is determined by the order of nucleotides in the DNA.
- It is shown by all proteins at the time of their synthesis on ribosome surface.
- The size of protein molecule depends upon number and type of amino acids comprising it.



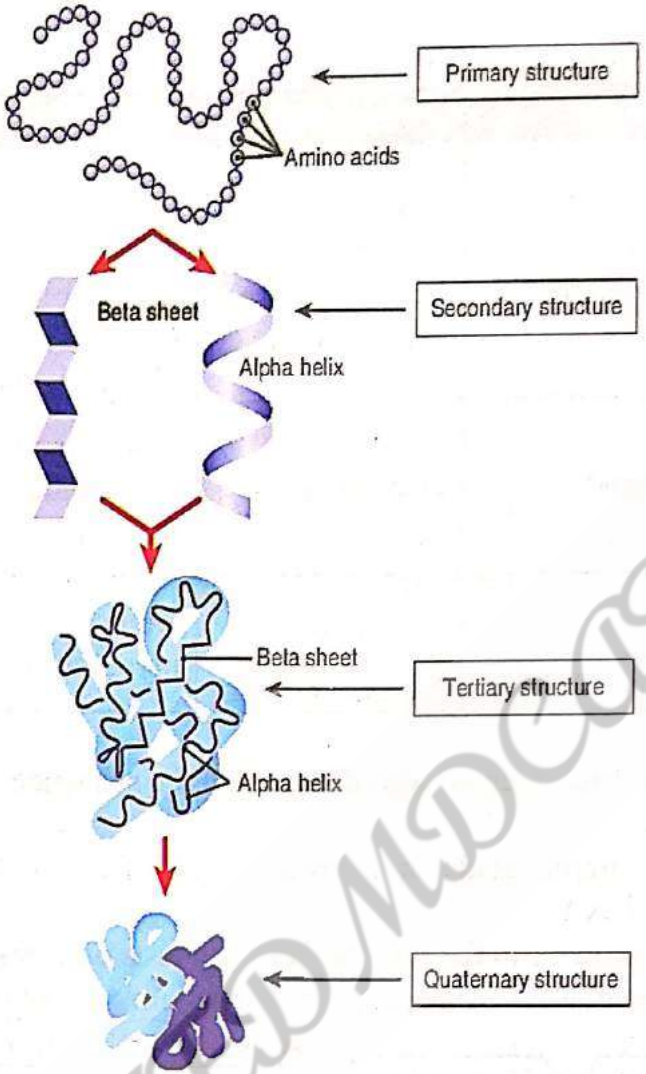
- A change in even a single amino acid, results in the failure of that protein, which may even lead to death, e.g., replacement of glutamic acid by valine in hemoglobin molecule results in formation of sickle hemoglobin, which fails to carry oxygen, the characteristic of sickle cell anemia ultimately leading to death.

Secondary Structure

- α- helix andβ- pleated sheets are its examples.
- ***α- helix*** is a very uniform geometric structure with ***3.6 amino acids*** in each turn of the helix.
- ***B-pleated sheet*** is formed by the folding back of the polypeptide.

CRITICAL CONCEPT!

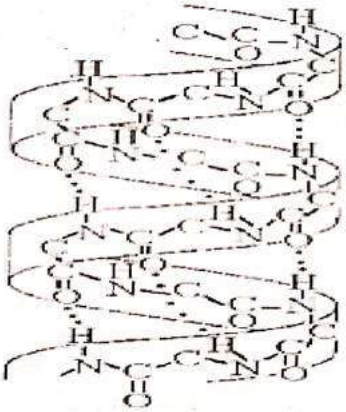
Hemoglobin:
The major hemoglobin in adult humans, hemoglobin A, is a heterotetramer composed of two α-globin and two β-globin polypeptides, each with an associated heme group. These are encoded by duplicated *HBA1* and *HBA2* genes and by the *HBB* gene, respectively.



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CRITICAL THINKING

7. Figure best illustrates the:



A. Secondary structure of a polypeptide
B. Tertiary structure of a polypeptide
C. Quaternary structure of a protein
D. Double helix structure of DNA

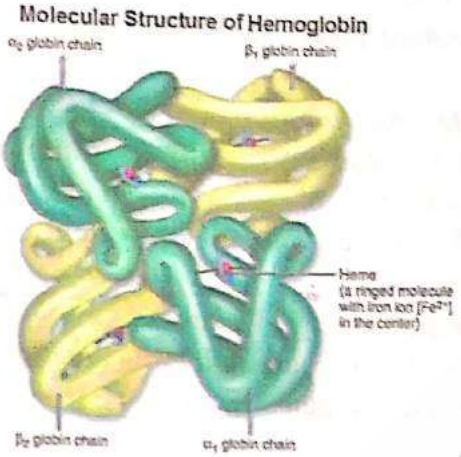
Tertiary Structure

In aqueous environment, the most stable tertiary conformation is that in which hydrophobic amino acids are buried inside while the hydrophilic amino acids are on the surface of molecule.

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Quaternary Structure

In many highly complex proteins, polypeptide tertiary chains are aggregated and held together by hydrophobic interactions. This specific arrangement is the quaternary structure of proteins.



CRITICAL THINKING

8. A peptide chain assumes secondary structure through the formation of:

A. Peptide bonds
B. Inter-chain ionic bonds
C. Intra-chain hydrogen bonds
D. Intra-chain disulphide bonds

Classification of Proteins

Feature	Fibrous Protein	Globular Protein
Shape	Fibrils form	Spherical or ellipsoidal
Structural organization	Secondary	Tertiary or quaternary
Solubility in aqueous media	Insoluble in aqueous media	Soluble in aqueous media
Crystal Nature	Non-crystalline	Can be crystallized
Elasticity	Elastic in nature	Inelastic in nature
Role	Play structural role	Play functional role
Stability	Stable	Unstable
Examples	Silk fibers, myosin, fibrin, keratin	Enzymes, antibodies, proteinaceous hormones, hemoglobin.

Important Structural Proteins	
Collagen	Bone and cartilage matrix
Elastin	Elasticity to tendon and ligaments
Keratin	Protective coverings e.g. hair, nails, quills, feathers, horns and beaks
Histone	Chromosome
Important Functional Proteins	
Enzymes	Control metabolism
Hormones	Regulation of physiological activities
Antibodies	Immunity
Hemoglobin	Transport of Gases
Fibrinogen	Blood Clotting
Ovalbumin	Storage of amino acids in eggs
Casein	Storage of amino acids in milk

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LIPIDS

- Lipids are a heterogeneous group of compounds related to fatty acids.
- They are ***insoluble in water*** but ***soluble in organic solvents*** like ether, alcohol, chloroform and benzenes.
- Their hydrophobic nature makes them best suited to be a ***structural component of cell membranes***.
- Lipids store ***double the amount of energy*** as compared to same amount of carbohydrates because of high proportion of C-H bonds and very low proportion of oxygen.
- May act as ***insulating layer*** e.g., waxes in exoskeleton of insects, and cutin which is an additional protective layer on the cuticle of epidermis of some plant organs. E.g. leaves, fruits, seeds.

CRITICAL CONCEPT!

Solubility of Lipids:
Only property by which we can define lipids is "its water insolubility".

Classification of Lipids

- Lipids are broadly classified into simple, complex and derived lipids, which are further sub-divided into different groups.
- ***Simple lipids*** are esters of fatty acids with various alcohols e.g., acylglycerols and waxes.
- ***Complex lipids*** contain other groups in addition to an alcohol and fatty acids e.g., phospholipids, glycolipids and lipoproteins.
- ***Derived lipids*** are derivates of simple and complex lipids e.g., terpenes, steroids, prostaglandins and cholesterol.

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Acylglycerols

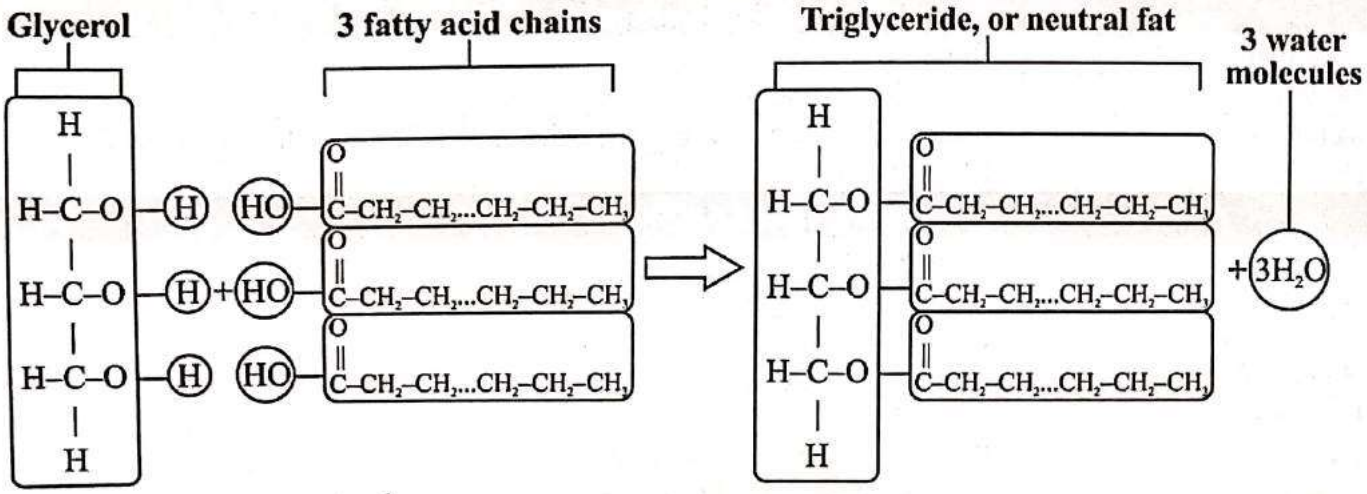
- These are ***esters of glycerol and fatty acids***.
- An ester is the compound produced as the result of a chemical reaction of an alcohol with acid and a water molecule is released. Such a reaction is called esterification.

$$\text{Fatty Acid} + \text{Glycerol} \xrightarrow{\text{Esterification}} \text{Acylglycerol} + H_2O$$

$$C_2H_5OH + HOOCCH_3 \longrightarrow C_2H_5OCOCH_3 + H_2O$$

- Glycerol is a tri-hydroxy alcohol which contains three carbons, each bearing an OH group.
- When three fatty acids combine with one glycerol, a triacylglycerol (triglyceride) is formed. Triacylglycerols are also called neutral lipids as all three OH^- groups of glycerol are occupied by fatty acids.

Three fatty acid chains are bound to glycerol by dehydration synthesis.



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Fatty Acid

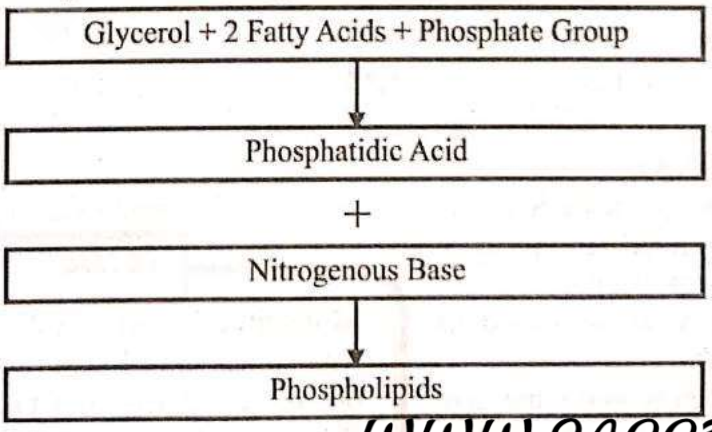
- A fatty acid is an organic compound containing one carboxylic acid group attached to a hydrocarbon chain.
- Fatty acids contain even number of carbon atoms (2-30). Each fatty acid is represented as R-COOH, where R is hydrocarbon tail.
- Solubility of fatty acids in organic solvents, hydrophobic nature and melting points depend upon number of carbon atoms and number of double bonds.
- Fatty acids are either saturated or unsaturated.
- Specific gravity 0.8.

Saturated Fatty Acid	Unsaturated Fatty Acid
No double bonds between carbon atoms	Upto six double bonds
Straight chain	Ringed /Branched
Solid at room temperature	Liquid at room temperature
Fats	Oils
Animals	Plants
	More useful for living things.

Fatty acid	Type	No. of Carbon	Source	Melting Point
Acetic acid	Saturated	2	Vinegar	16.6°C
Butyric acid	Saturated	4	Butter	-8°C
Palmitic acid	Saturated	16	Palm tree	63.1°C
Oleic acid	Mono-unsaturated	18	Olives	4°C

Phospholipids

- They are the derivatives of ***phosphatidic acid*** by addition of one of the nitrogenous base.
- One end of phospholipid molecule (head), containing the phosphate group and nitrogenous compound is polar and hydrophilic. Other end (tail) containing the fatty acid side chains are non-polar and hydrophobic.

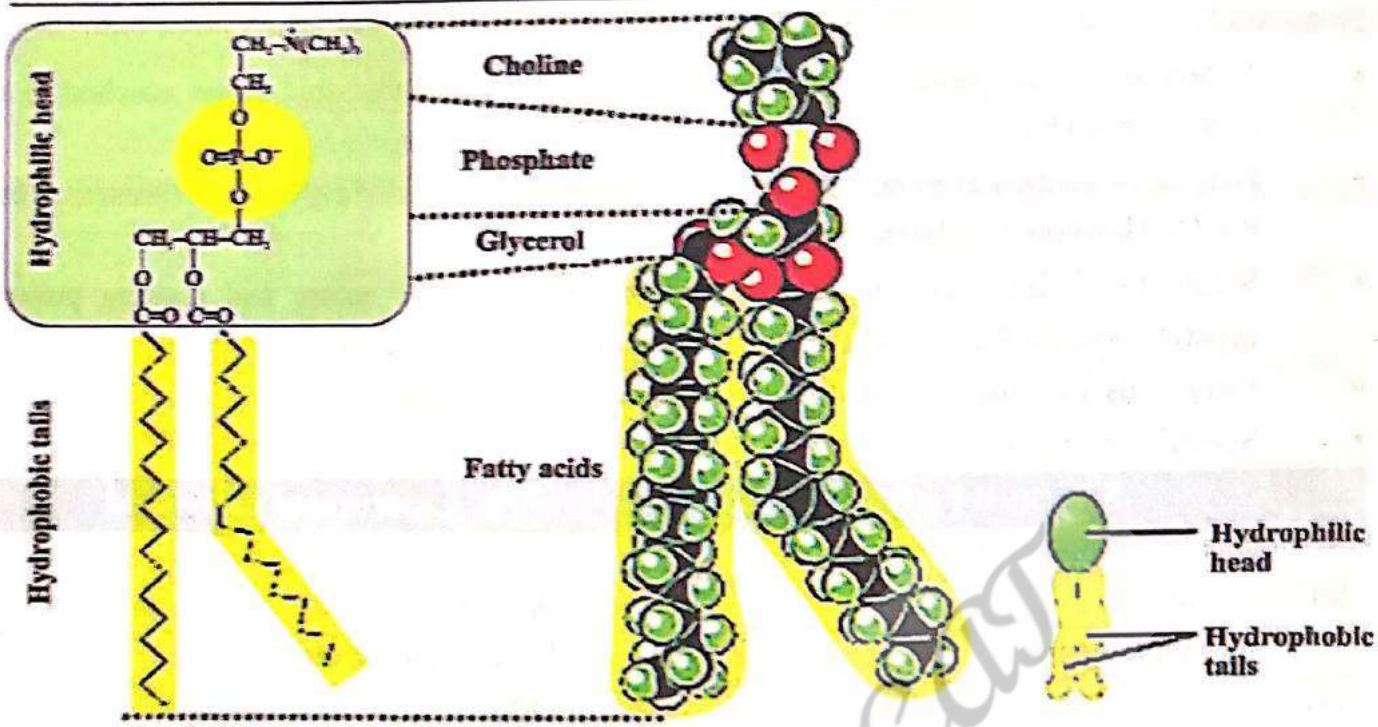


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Example

- ***Phophatidylcholine*** is one of its commonest examples, also called ***lecithin.***

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Function

- They are frequently associated with ***biological membranes*** and form lipid bilayer.

NUCLEIC ACIDS (RNA)

Ribonucleic Acid (RNA)

- RNA is polymer of ribonucleotides.
- The RNA molecule occurs as single strand, which may be folded back on itself to give double helical characteristics. In this case, cytosine pairs with guanine and adenine with uracil.
- RNA is synthesized by DNA in a process known as ***transcription***.

Nucleotides of RNA

Nitrogenous Base	Nucleoside (Ribose + Base)	Nucleotides (Nucleoside + Phosphoric Acid)		
Adenine	Adenosine	AMP	ADP	ATP
Guanine	Guanosine	GMP	GDP	GTP
Cytosine	Cytidine	CMP	CDP	CTP
Uracil	Uridine	UMP	UDP	UTP

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Types of RNA

Messenger RNA (mRNA)

- It takes the genetic message from the nucleus to ribosome in the cytoplasm, where amino acids are arranged to form a specific protein molecule.
- It consists of a single strand of ***variable length***.
- Its length depends upon the size of the gene as well as the protein for which it is taking the message. For example, for a molecule of

CRITICAL CONCEPT!

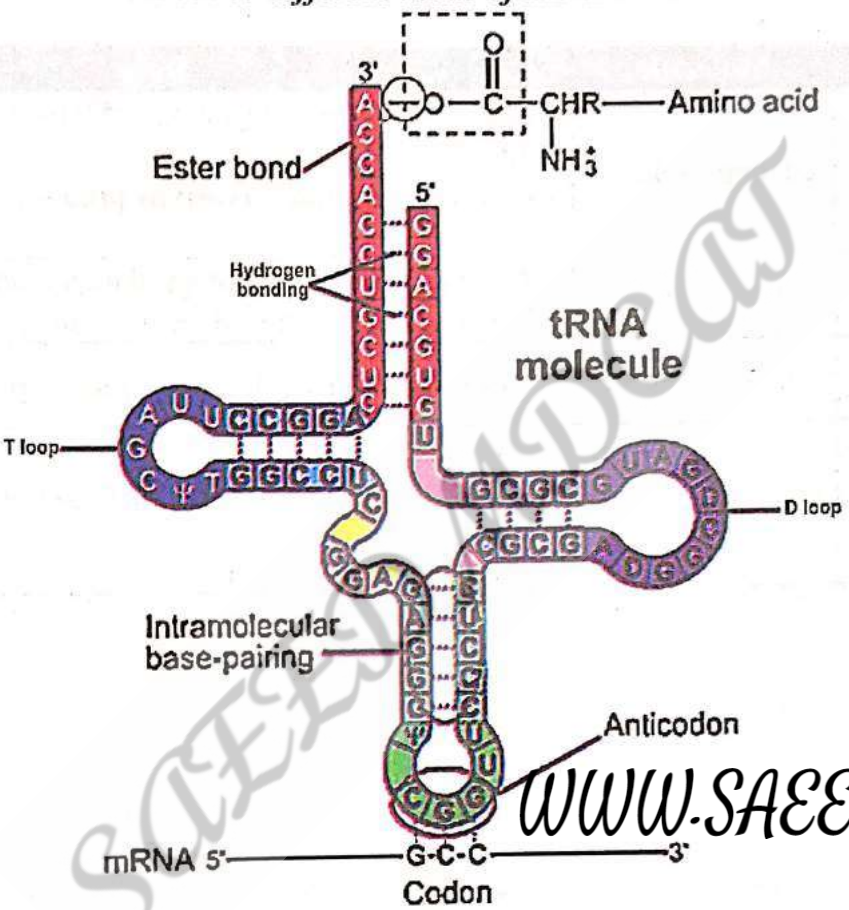
Molecular Directions during Translation: Ribosomes translocate always from 5' to 3' on mRNA during the process of translation. While polypeptide chains are always synthesized from N to C terminal.

1000 amino acids, mRNA will have the length of 3000 nucleotides.

- Actually every three nucleotides in mRNA encode a specific amino acid; such triplets of nucleotides along the length of mRNA are called ***codons of genetic codes***.

Transfer RNA (tRNA)

- It is ***smallest in size***.
- It is a single stranded molecule but it shows a duplex appearance at its some regions.
- It transfers amino acid molecules to the site where peptide chains are being synthesized.
- There is one specific tRNA for each amino acid. So, there are at least 20 kinds of tRNA molecules. tRNA picks amino acids and transfers them to ribosomes.
- Human cells contain about ***45 different kinds of tRNA molecules***.



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Ribosomal RNA (rRNA)

- It is the ***major portion of RNA*** in the cell, and may be upto 80% of the total RNA.
- It is transcribed by the genes present on the DNA of several chromosomes.
- These have the largest size among the RNA.
- It acts as machinery for the synthesis of proteins.
- It is strongly associated with the ribosomal proteins where 40 – 50 % of it is present.

Feature	mRNA	tRNA	rRNA
Function	Takes message from DNA to ribosomes	Transfers amino acids to ribosomes	Formation of ribosomes
Length	Single strand of variable length	Length of 75-90 nucleotides	Double helix with constant length
Percentage	3-4%	10-20%	80%

CRITICAL THINKING

9. **Relation between amino acid and protein is similar to the one found between:**
 A. Thymine and uracil
 B. Glucose and fructose
 C. Nucleosides and nucleic acid
 D. Nucleotides and nucleic acid

CONJUGATED MOLECULES

Conjugated Molecules

- Two different molecules, belonging to different categories, usually combine together to form conjugated molecules.

Components	Molecule	Role
Carbohydrates + Proteins	Glycoproteins	Cellular secretions, Integral part of biological membranes, Egg albumen. Enzyme, Hormone, Transport protein, Structural protein, Receptors.
Carbohydrates + Lipids	Glycolipids	Integral component of biological membranes and brain. White matter of brain, Myelin sheath of nerve fiber.
Nucleic acid + Histones	Nucleohistones	Chromosome + Regulation of gene expression.
Lipids + Proteins	Lipoproteins	Milk, Blood, Egg yolk membrane, Cell nucleus, Chloroplast of plant, Bacterial antigen and viruses, Cutin: In cuticle Ruber: Wall of cork cell.

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TOPIC-4 » CELL STRUCTURE AND FUNCTION

COURSE CONTENT

- Introduction to Cell
- Compare the Structure of Typical Animal and Plant Cell
- Cell Wall
- Plasma Membrane
- Cytoplasm
- Cell Organelles: Ribosomes, Endoplasmic Reticulum, Golgi Complex, Lysosomes, Vacuoles, Mitochondria, Plastids/Chloroplasts, Nucleus
- Compare the Structure of Typical Prokaryotic and Eukaryotic Cells

INTRODUCTION TO CELL

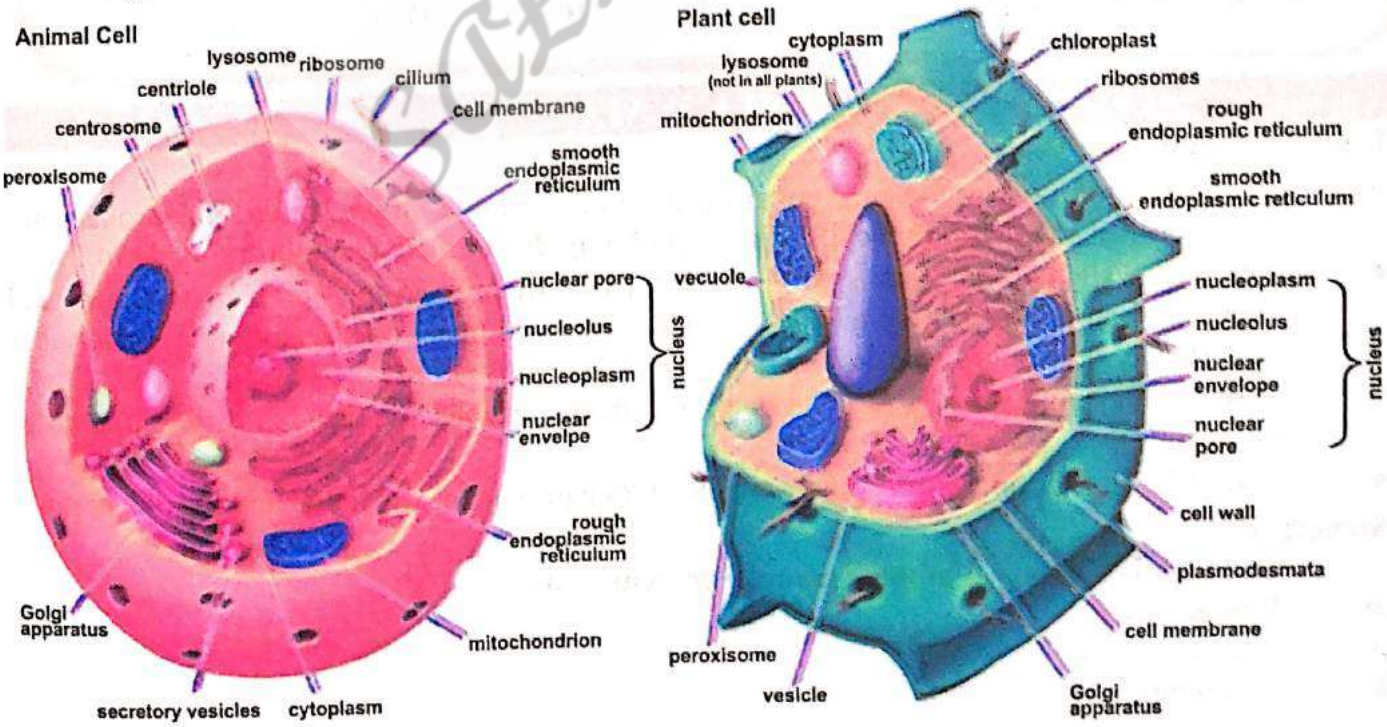
- The cell can be defined as 'the structural and functional unit of life/living organisms' and is the smallest unit that can carry out all activities of life.
- After the discovery of the cell in 17th century, a lot of information's have been collected by different researchers. This information's have been summarized in the form of ***cell theory***.
- The modern technology enables the Biologist to isolate various components of the cells including its organelles by a process of ***cell fractionation***.
- During cell fractionation, the tissues are homogenized or disrupted with special instruments and various parts of the cells are separated by density gradient centrifugation.
- The various cellular parts separate out in different layers depending upon their size, weight, and density of the medium.
- A cell consists of the following basic components:

(i) Plasma membrane, also cell wall in plant cells
(ii) Cytoplasm, containing cells organelles
(iii) Nucleus, with nuclear or chromatin material

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COMPARE THE STRUCTURE OF TYPICAL PLANT AND ANIMAL CELL

In the traditional system of classification, all organisms are divided into plants and animals. The main comparative features between animal and plant cells are shown in the figure below:



These comparative features are also listed in the following table.

Features	Animal Cell	Plant Cell
Cell wall	×	✓
Plastids	×	✓
Glyoxysomes	×	✓
Centrosome (Centrioles)	✓	×
Mitotic Apparatus	Spindles + Asters	Spindles Only
Cytokinesis	Inwards	Outwards
Lysosomes	✓	×
Flagella	✓	×
Phagocytosis	✓	×
Nucleus	Central	Peripheral
Vacuoles	Small and many	Large and single
Storage Products	Glycogen	Starch
Cellular Shape	Do not have fixed shape	Have fixed shape

CRITICAL THINKING

1. **Select the correct answer using the codes given below the lists:**

	Sub-structures		Functions
A	Nucleosome	1	Cell adhering junctions
B	Tubulin	2	Battery of degradative enzymes
C	Desmosome	3	Structural units of chromatin
D	Lysosome	4	Protein units of microtubules
		5	Oxidative phosphorylation

A. A=2, B=5, C=4, D=3 B. A=3, B=4, C=1, D=2
C. A=3, B=5, C=4, D=2 D. A=2, B=4, C=1, D=3

CELL WALL

Introduction to Cell Wall

- It is the outermost non-living covering present in plants, algae, fungi and prokaryotic cells while absent in animal cells. This is probably due to their locomotory mode of life.
- The cell wall of plant cell is different from that of prokaryotes, both in structure and chemical composition. Prokaryotic cell walls lack cellulose; its strengthening material is peptidoglycan or murein while fungal cell wall contains chitin.
- It is ***secreted by protoplasm*** of the cell and have variable thickness in different cells of the plant.
- The cell wall is porous ***(called pits)*** and allows free passage of water and dissolved material.

Structure

Cell wall is composed of three main layers which are:

- Primary wall
- Middle lamella
- Secondary wall

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(i) **Primary Wall**

The primary wall is a true wall and develops in newly growing cells. Some plant cells possess only primary cell wall such as leaves, storage cells and young growing cells. The primary wall is composed of:

- ***Cellulose*** micro-fibrils are arranged in a crisscross arrangement. The microfibrils are held together by hydrogen bond to provide ***high tensile strength***.
- Some amount of ***pectin and hemicellulose*** **is** also deposited in it.
- The outer part of primary cell walls of plant epidermis in usually impregnated with ***cutin*** and ***wax***, forming a permeability barrier known as plant ***cuticle***.

(ii) **Middle Lamella**

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The middle lamella is first to be formed in between the primary walls of the neighboring cells.

- It is formed of sticky gel-like magnesium and calcium salts and pectin which help to stick the neighboring cells together.

(iii) **Secondary Wall**

The secondary wall is formed between the primary cell wall and plasma membrane and is formed when the cell is fully grown. It is comparatively thick and rigid as compared to primary wall.

- Chemically, it is composed of ***inorganic salts, silica, waxes, lignin***, and ***cutin*** etc.
- Lignin cements and anchors cellulose micro-fibrils together and it is mainly responsible for rigidness.

Functions of Cell Wall

Cell wall is very important. It performs following important functions:

(i) It provides a ***definite shape*** to the cell.

(ii) It prevents the cells from osmotic lysis, when cells are placed in hypotonic external environment.

(iii) It provides ***protection*** to inner parts of cells and ***does not act as a barrier*** to the materials passing through it.

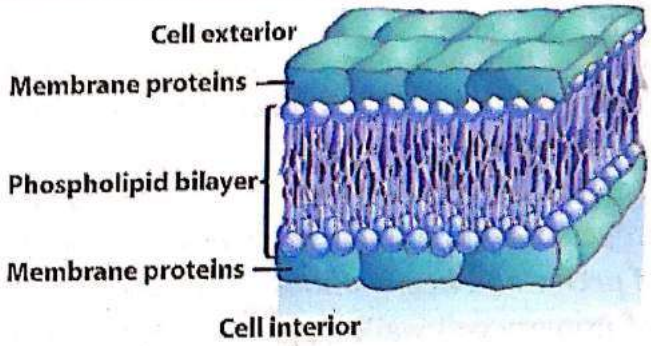
PLASMA MEMBRANE

- Cell membrane is the outer most boundary of the animal cell while covered by cell wall in a plant cell. It is found in all living prokaryotic and eukaryotic cells
- Plasma membrane is about 7 nm thick.
- Chemically composed of:
 - Proteins (60- 80 %)
 - Lipids (20- 40 %)
 - Small amount of carbohydrates is also present in the form of glycolipids and glycoproteins.

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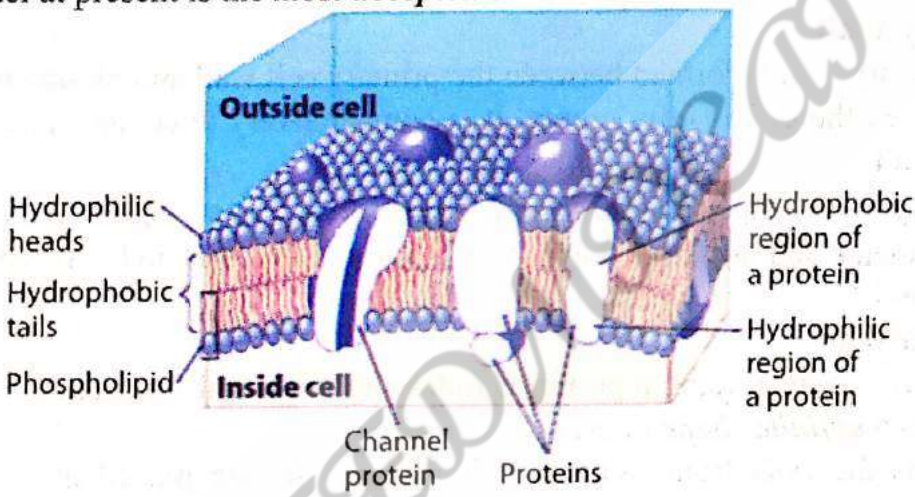
Unit Membrane Model

- This model was presented by J. David Robertson in 1959.
- According to unit membrane model, the cell membrane is composed of lipid bilayer sandwiched between inner and outer layer of proteins.
- This structure has hydrophobic component i.e. central non-polar part of phospholipid molecules and a hydrophilic part i.e., outer polar component of phospholipids and globular proteins covering both sides as shown in the following diagram.



Fluid Mosaic Model

- This model was proposed by S. J. Singer and G. L. Nicolson in 1972.
- According to fluid mosaic model, protein layers are not continuous and are not confined to the surface of the membrane but are embedded in lipid layers in a mosaic manner. These protein molecules may function as a gateway (charged pore) for the transport of materials.
- This model at present is the ***most accepted one***.



Role of Different Molecules

- ***Phospholipids*** form lipid bilayer.
- ***Cholesterol*** helps to stabilize this lipid bilayer.
- ***Channel proteins*** allow a particular molecule or ion to cross the plasma membrane freely.
- ***Carrier proteins*** selectively interact with a specific molecule or ion so that it can cross the plasma membrane.

CRITICAL THINKING

2. The function of channel proteins in membrane is to:

A. Transport phospholipids across the membrane
B. Act as receptor molecules which can bind to ligands
C. Permit the diffusion of specific substances through the membrane
D. Bind to a substance on one side and release it on the other side of the membrane

- Some plasma membrane proteins have enzymatic functions. They perform metabolic reactions directly e.g. ***adenylate cyclase*** catalyzes the transformation of ***ATP to cAMP***, a ***second messenger***, used for intracellular signal transduction, such as transferring into cells the effects of hormones like glucagon and adrenaline because they cannot pass through the plasma membrane.

- Some proteins in the plasma membrane ac as ***receptors*** and receive signals from the other cells/endocrine glands.
- ***Glycoproteins*** and ***glycolipids*** are found on cell surface and help in recognition. Mostly these molecules act as cell surface markers.

Transport Mechanisms across Plasma Membrane

- Cell membrane is a ***differentially permeable*** or ***selectively permeable membrane***, allowing only the selective substances to pass through it.
- ***Lipid soluble*** substances pass through cell membrane more easily than others.
- Many small gas molecules, water, glucose etc. being neutral can easily cross.
- Ions being charged particles have some difficulty in crossing.

Passive and Active Transport

Passive Transport	Active Transport
High conc. → Low conc.	Low conc. → High conc.
Along the concentration gradient	Against the concentration gradient
Downhill movement	Uphill movement
Without use of cell energy(ATP)	With use of cell energy(ATP)

Diffusion and Osmosis

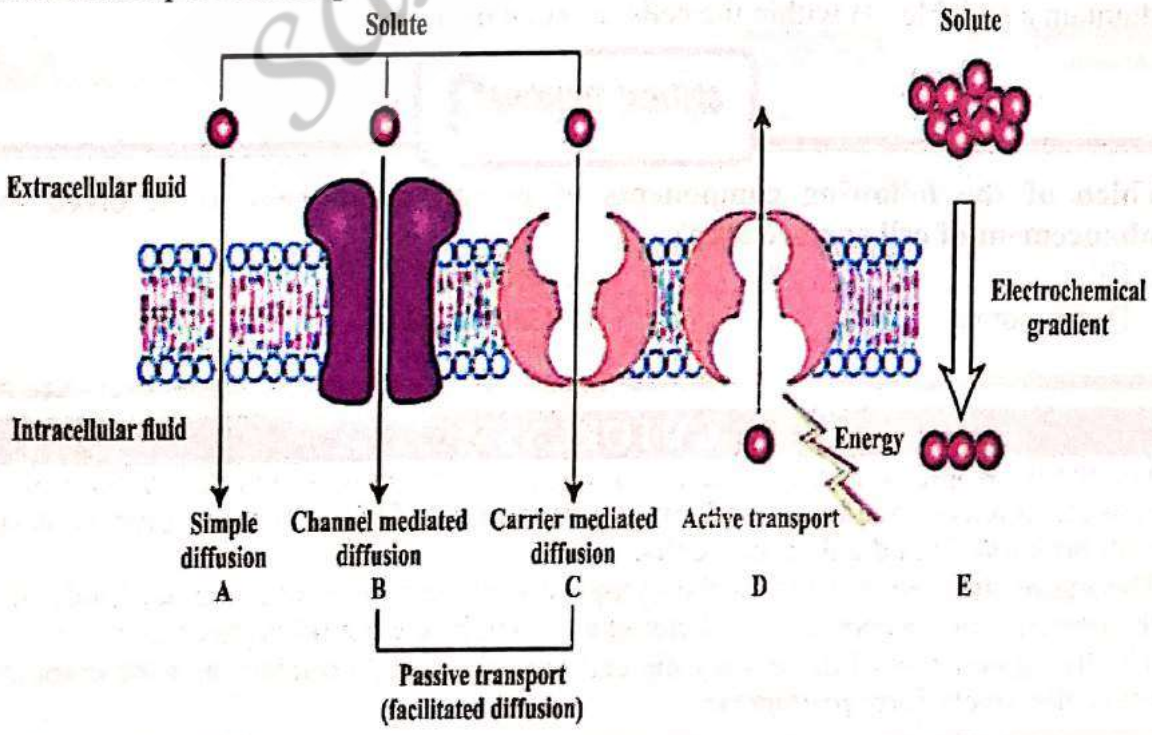
- Movement of solute molecules from higher concentration to lower concentration is called diffusion e.g. movement of respiratory gases.
- Movement of water molecules across the membrane from higher water potential to lower water potential is called osmosis.

Facilitated Diffusion

- It is a type of carrier mediated transport in which molecules move from higher concentration to lower concentration with the help of carrier proteins.

CRITICAL CONCEPT!

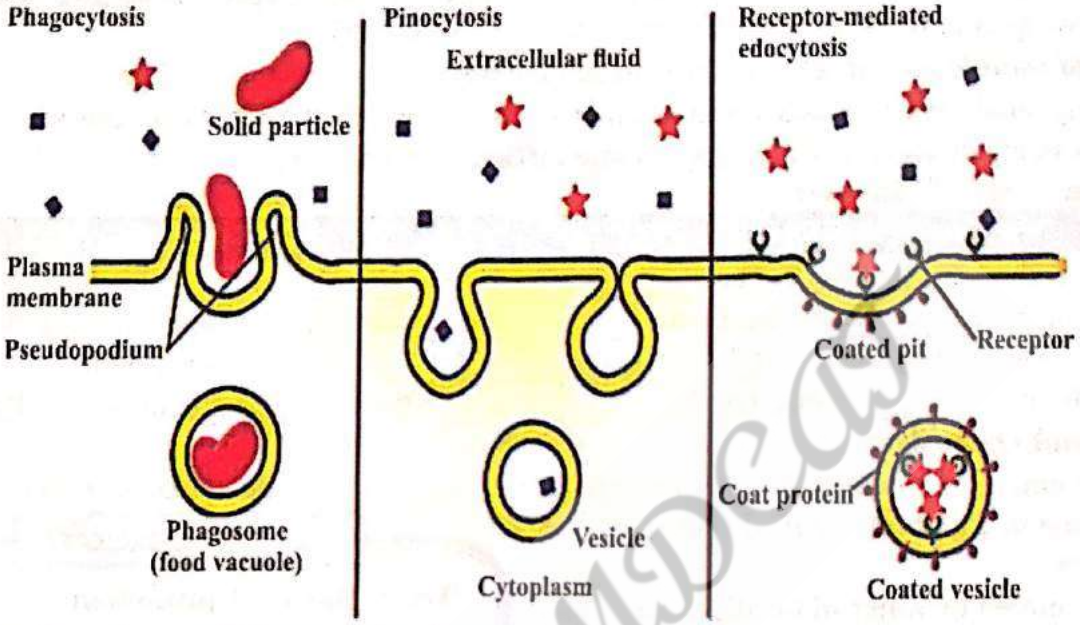
Brush Border Epithelium:
Brush border epithelium is a stria of microvilli on the plasma membrane of an epithelial cell (as in a kidney tubule or in small intestine) that is specialized for absorption of various substances.



Endocytosis and Exocytosis

- Intake of materials along the infoldings of cell membrane in the form of vacuole is called endocytosis.
- Intake of material in solid form is called ***phagocytosis*** while intake in fluid form is called ***pinocytosis***.

Endocytosis



Some Other Functions of Plasma Membrane

Plasma membrane regulates cell's interaction with its environment by controlling transport of materials across the cell. Transport across plasma membrane occur to;

(i) Obtain nutrients
(ii) Excrete waste substances
(iii) Secrete useful substances
(iv) Generate ionic gradients essential for nervous and muscular activities
(v) Maintain a suitable pH within the cells for enzyme activity

CRITICAL THINKING?

3. Which of the following components of plasma membrane is involved in the enhancement of cell surface area?

A. Cilia
B. Microvilli
C. Desmosomes
D. Gap junctions

CYTOPLASM

- The word cytoplasm literally means 'living gel of the cell, and is described as the region between nuclear membrane and plasma membrane. This is the common component of both prokaryotic and eukaryotic cells.
- The major difference between the cytoplasm of these two fundamental kinds of cells is the presence or absence of cytoskeleton and membrane bound organelles.
- The living contents of the eukaryotic cell are divided into nucleus and the cytoplasm, the two collectively form ***protoplast***.

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- Cytoplasm consists of an aqueous ground substance containing a variety of cell organelle and other inclusions such as insoluble waste and storage products.

Composition

Cytoplasm contains:

(i) Cytosol
(ii) Fundamental molecules of life
(iii) Cell organelles

(i) **Cytosol**

It is the soluble part of cytoplasm. Chemically, it is about ***90% water*** and forms a solution containing all the fundamental molecules of life, i.e., amino acids, sugars, fatty acids, nucleotides, vitamins, salts and dissolved gases.

(ii) **Fundamental Molecules of Life**

- Some of them are in ionic form.
- Small molecules form true solutions.
- Some large molecules form colloidal solutions. Colloidal solution may be sol (non-viscous) or gel (viscous).

(iii) **Cell Organelles**

In living cells, the cytoplasm contains several cell organelles such as endoplasmic reticulum, mitochondria, Golgi complex, nucleus, plastids, ribosomes, lysosomes and centrioles.

Function of Cytoplasm

The most important functions of cytoplasm are:

(i) It acts as a ***store house*** of vital chemicals.
(ii) It is a ***site of certain metabolic pathways*** e.g. ***translation***, ***glycolysis***, ***glycogenolysis*** and ***gluconeogenesis***.

CELL ORGANELLES

An organelle is a sub-cellular structure that has one or more specific jobs to perform in the cell, much like an organ does in the body. Prokaryotic cells are equipped with few type of organelles while eukaryotic cells are equipped with many different type of organelles, forming true labor of division in these cells.

Non-Membranous	Single Membranous	Double Membranous
Ribosomes	Endoplasmic Reticulum	Mitochondria
Centrioles and Microtubule	Golgi apparatus	Plastids
	Lysosomes	Nucleus
	Glyoxysomes	
	Peroxisomes	
	Vacuoles	

Discovery of Organelles

Organelles	Discovered By
Ribosomes	George Emil Palade
Centrioles	Edouard Van Beneden
Cytoskeleton	Nikolai K. Koltsov
Endoplasmic Reticulum	Keith R. Porter, Albert Claude, Brody Meskers and Ernest F. Fullam
Golgi apparatus	Camillo Golgi
Lysosomes	C. R. De Duve

Peroxisomes	C. R. De Duve
Glyoxysomes	Harry Beevers
Mitochondria	Richard Altmann
Nucleus	Robert Brown

RIBOSOMES

Ribosomes were first observed using electron microscope as tiny and dense granules. These are roughly spherical, non-membranous bodies found in both eukaryotic as well as prokaryotic cells.

Chemical Composition

- Ribosomes are ***ribonucleo- proteins*** particles.
- Ribosomes consist of ***RNA*** and ***proteins*** in almost equal proportion.

Assembly of Ribosomes

- Ribosomes are assembled in the ***nucleolus***.
- From nucleolus they are transported to the cytoplasm through nuclear pores.

CRITICAL CONCEPT!

Ribosomes Found in Organelles: Being organelles of prokaryotic origin, mitochondria and chloroplast have 70S ribosomes and small circular DNA in their matrix.

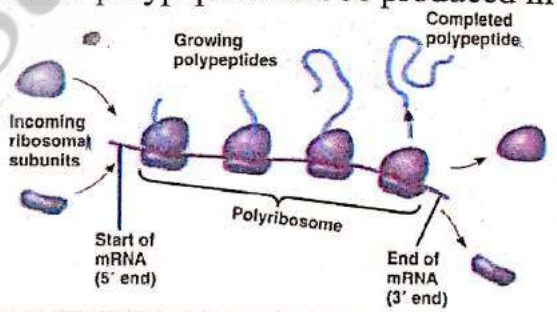
Form and Physical Structure

- They exist in two forms, either dispersed in the cytoplasm or attached with rough endoplasmic reticulum (RER) as tiny granules.
- Ribosomes consist of ***two subunits***: larger subunit and smaller subunit.
- Attachment of both subunits is controlled by Mg^{2+} ***ions***.
- Ribosomes are attached to 5' end of mRNA through smaller subunits.

	Ribosome	Larger Subunit	Smaller Subunit
Prokaryotic Ribosomes	Smaller, 70S	50S	30S
Eukaryotic Ribosomes	Larger, 80S	60S	40S

Functions

- Ribosomes are the factory for ***protein synthesis (translation)***.
- A group of ribosomes attached to mRNA is known as ***polysome*** **or** ***polyribosome***. In this way, several copies of same polypeptide can be produced in very less time.



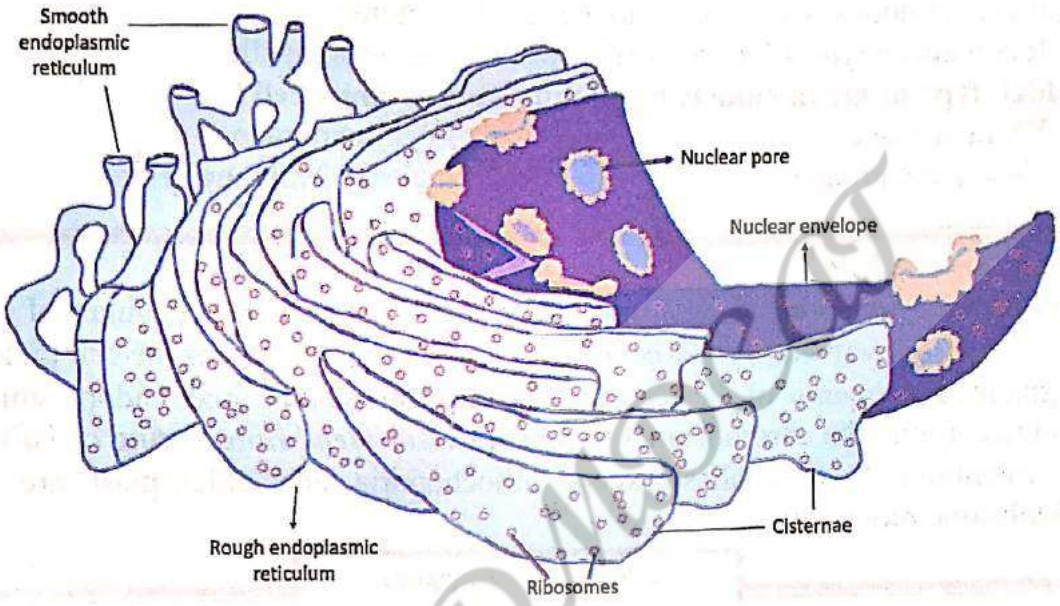
CRITICAL THINKING?

4. RNA binds with _____ ribosomal unit during translation in mitochondrial matrix.

A. 30S
B. 60S
C. 50S
D. 40S

ENDOPLASMIC RETICULUM

- Network of interconnected channels extending and often continues with cell membrane to the nuclear membrane is called endoplasmic reticulum.
- They vary in appearance from cell to cell.
- ***Cisternae*** are spherical or tubular membranes which separate the material present in these channels from that of cytoplasmic material.
- In skeletal and cardiac muscle cells, the modified form of SER is known as ***sarcoplasmic reticulum*** which is specialized for storage of Ca^{+2}in their lumen. If many ribosomes are attached on the small parallel cisternae of RER, then it is called ***ergastoplasm***. In nerve cells, the ergastoplasm is known as Nissl's granules/bodies.



Types and Functions

There are two **morphological forms** of endoplasmic reticulum; RER and SER.

Features	Rough Endoplasmic Reticulum	Smooth Endoplasmic Reticulum
Ribosomes	Ribosomes are attached with their outer surface	Ribosomes are not attached with their outer surface
Connection with the nuclear membrane	RER is directly connected with outer nuclear membrane	SER is not directly connected with outer nuclear membrane
Stability	More stable structure	Less stable structure
Composition	Mainly composed of vesicular cisternae	Mainly composed of tubular cisternae
Relative abundance in body	Abundantly occur in the cells/tissues/organs which are actively engaged in protein synthesis and secretion	Abundantly occur in the cells concerned with glycogen and lipid metabolism
Example of Tissues/organs	Liver, pancreas and goblet cells etc.	Adipose tissues, muscles etc.
Functions	• Protein synthesis / Translation. After synthesis, they are either stored in the cytoplasm or transported out of the cell through these channels	• Metabolism of various types of molecules particularly lipids. • Involved in detoxification harmful drugs. • Transmission of impulses

CRITICAL THINKING?

5. **Which of the following will not be channelized through RER?**
 A. Immunoglobulins B. Thyroid stimulating hormone
 C. Interferons D. Arginase
6. **Which of the following statement about the endoplasmic reticulum is correct?**
 A. It is involved in Glycogenolysis
 B. It consists of a collection of unconnected vesicles
 C. It is continuous with outer mitochondrial membrane
 D. It contain enzymes for the breakdown of cellular organelles
7. **Which type of membrane is most abundant within a cell?**
 A. ER membrane B. Golgi membrane
 C. Plasma membrane D. Nuclear membrane

General Functions of E.R

- They provide ***mechanical support*** to the cell, so that its shape is maintained
- They are also involved in ***transport of materials*** from one part of the cell to the other.
- Fragmented elements of disintegrated nuclear membrane and endoplasmic reticulum arranged around the chromosomes to ***form nuclear membrane during cell division***.
- All membranous organelles except mitochondria and chloroplast are formed by endoplasmic reticulum.

CRITICAL CONCEPT!

Proteins Synthesized by Different Classes of Cellular Ribosomes	
Location of Ribosomes	**Classes of Protein Synthesized**
Membrane Free Ribosomes	Soluble cytosolic protiens, Extrinsic membrane proteins, Localized to the cytoplasmic surface (e.g., actin, spectrin), Mitochondrial and chloroplast proteins encoded by nuclear DNA, Peroxisomal protiens
ER Membrane Bound Ribosomes	Secreted proteins, Integral plasma proteins, Lysosomal proteins, ER proteins, Golgi complex proteins, Extrinsic membrane proteins localized to the extra-cytosolic surface (e.g., Fibronectin)

GOLGI APPARATUS

Introduction

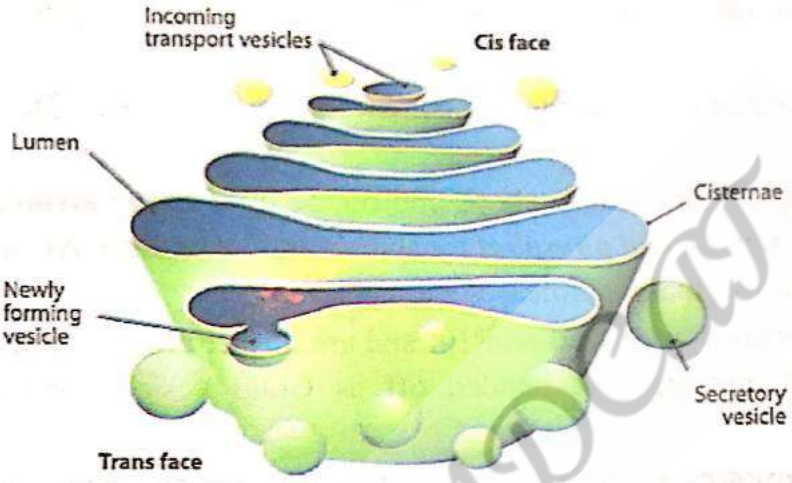
- Single cisternal sac is called ***Golgi body***.
- Stack of cisternae sacs is called ***Golgi apparatus***.
- Stack of cisternae sacs with associated vesicles is called ***Golgi complex***.
- Golgi apparatus in plants is called ***Dictyosomes*** which are used in construction of cell wall.

SCIENCE MEDICAT

Structure

- Golgi apparatus is a stack of flattened, membrane bound sacs called ***cisternae***.
- Golgi complex is a complex system of interconnected tubules around the central stacks. The cisternae together with associated vesicles are called Golgi complex.
- Golgi apparatus has two faces i.e. forming face and maturing face.
- ***Forming face*** is outer face also called as 'cis face'. Vesicles that bud off from smooth endoplasmic reticulum are fused together to form cisternae of Golgi apparatus at forming face.
- ***Maturing face*** is inner face also called as 'trans face'.
- Secretory granules/ Golgi vesicles are pinched off from maturing surface.

Golgi Apparatus



Functions

- The main function of Golgi bodies is the ***cell secretion***.
- They are involved in ***modification of molecules***. Most important modifications are addition of carbohydrates into proteins and lipids and subsequent synthesis of ***glycoconjugates***.
- During cytokinesis in plant cells, these are involved in formation of ***phragmoplast***.
- An important function of Golgi apparatus is the ***formation of primary lysosomes***.
- ***Formation of acrosome*** during spermatogenesis.

CRITICAL CONCEPT!

Endomembrane system:
The endomembrane system is a group of membranes and organelles in eukaryotic cells that works together to modify, package, and transport lipids and proteins. It includes the nuclear envelope, endoplasmic reticulum and Golgi apparatus, lysosomes and vesicles.

Pathway and Fate of Processed Vesicles

Ribosomes → Endoplasmic reticulum → Transport vesicles → Golgi apparatus

Packed inside a membrane

Lysosomes

Excretory granules

Golgi Vesicles

Modification of proteins and lipids by adding carbohydrates and converting them into glycoproteins and glycolipids.

SCIENCE MADE EASY

CRITICAL THINKING

8. **Golgi apparatus is involved in processing of:**
 A. Salivary amylase B. Glucokinase
 C. Phenylalanine hydroxylase D. EcoR1

LYSOSOMES

Introduction

- Lysosomes (Lyso = Splitting: Soma = Body) are cytoplasmic organelles which are found in most eukaryotic cells except RBCs and are different from others due to their morphology.
- These were isolated as a separate component for the first time by De Duve in 1949.

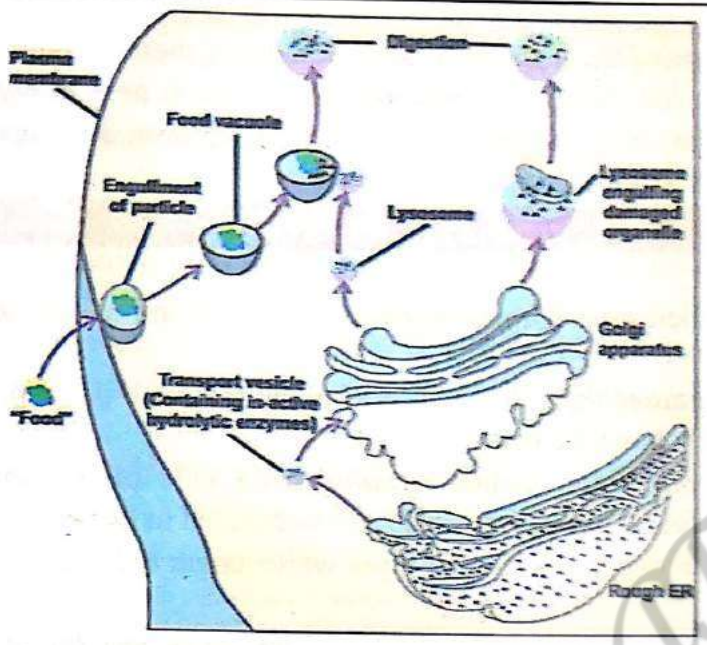
Structure

- These are roughly spherical in shape and bound by a ***single membrane*** and are simple sacs (vesicles) rich in ***acid phosphatase*** and several other digestive or ***hydrolytic enzymes*** like carbohydrases, lipases, proteases and nucleases.
- These enzymes are synthesized on RER and are further processed in the Golgi apparatus. The processed enzymes are budded off as Golgi vesicles and are called ***primary lysosomes.***
- ***Secondary lysosomes*** are formed by the fusion of primary lysosome with food vacuole known as phagosome (phagocytic food vacuole).
- ***Tertiary lysosomes or residual bodies*** contain undigested material after the absorption of digested food into the cytoplasm. In unicellular organisms, these are removed outside of cell by exocytosis while in multicellular organisms, these are retained in the cells as lipofuscin granules.

Functions

- Any foreign object that gains entry into the cell is immediately engulfed by the lysosomes and is completely broken into simple digestible pieces. This process is known as ***phagocytosis.***
- The ingested food of cell is stored in vesicles, called food vacuoles. Once a lysosome has fused with food vacuole, the resulting structure is called secondary lysosome. Digested products are absorbed by cytoplasm while remaining wastes containing vesicle is now called contractile vacuole. This is called ***intracellular digestion.***
- They are also involved in the ***autophagy.*** During this process some old, worn out parts of cells, such as mitochondria are digested. Such lysosomes are called autophagosome. Such process also occurs during starvation.
- Their enzymes can also result in ***degeneration of cell,*** as may occur during some developmental processes. This type of cell death is called autolysis. Removal of tadpole tail during metamorphosis is an example of lysosomal activity.
- Lysosomes also release enzymes for ***extracellular digestion.***

SCIENCE MOCAT

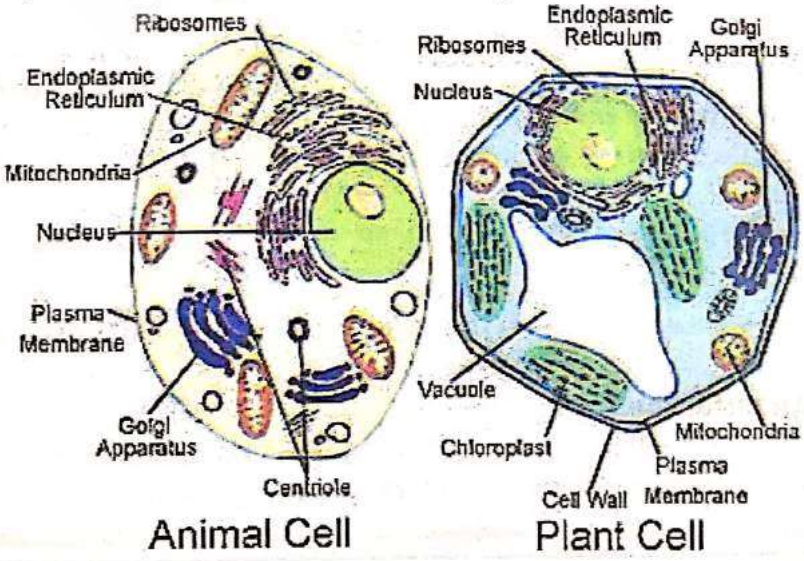


Storage Diseases

- Several congenital diseases have been found to be due to accumulation within the cell of substances such as glycogen or glycolipids. These are called storage diseases. 20 such diseases have been discovered so far.
- These diseases are produced by a mutation that affects one of the lysosomal enzymes involved in the catabolism.
- In ***glycogenosis type II disease***, the liver and muscle appear to be filled with glycogen within membrane bound organelles. In this disease, an enzyme that degrades glycogen to glucose is absent.
- ***Tay-Sach's disease*** is because of absence of an enzyme that is involved in the catabolism of lipids. Accumulation of lipids in brain cells leads to mental retardation and even death.

VACUOLES

- They are present both in plant and animal cell.
- In plant cell, a large central vacuole is present that is formed by coalescence of smaller vacuoles.
- In animal cell, small but numerous vacuoles are present.



Functions

- They serve to ***expand*** the plant cells without diluting their cytoplasm
- They act as a site for ***storage of water and cell products or metabolic intermediates***.
- They maintain the cells' ***turgor***, responsible for support, and rigidity of the leaves and young parts of the plants.

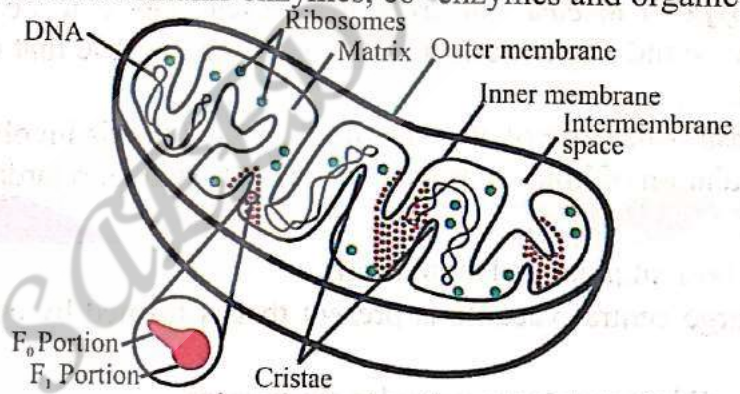
MITOCHONDRIA

Introduction

- They are also called ***power house/battery*** of the cell and busiest and active organelle in cell.
- Their ***size and number*** variable e.g. few to many thousand per cell, and depending on the physiological activity of the cell.
- They are ***self-replicating,*** contain ***circular DNA*** (1% of the total DNA of cell) ***and ribosomes***; thus, some proteins may also be synthesized in them.
- The diameter of mitochondria is 0.2-1.0 µm while length is 1-4 µm

Structure

- When seen under compound microscope they ***appear as vesicles, rods, filaments***.
- When seen under electron microscope, then it shows that they are bound by two membranes, a smooth outer membrane and an inner one forming infoldings (***cristae***) in mitochondrial matrix and they show complex morphology.
- The inner surface of cristae in the mitochondrial matrix contains small knob like structure called ***oxysomes /F_1/elementary particles.***
- ***Mitochondrial matrix*** contains enzymes, co- enzymes and organic and inorganic salts.



Functions

- They manufacture and supply **energy** to the cell.
- Enzymes in mitochondrial matrix help in metabolic processes like ***Krebs cycle, aerobic respiration***, and ***fatty acid metabolism***. These processes extract energy from the organic food and convert them into ATP, an energy rich compound, which provides energy to the cell on demand.
- ADP is regenerated by mitochondria into ATP.

CRITICAL THINKING

9. It is related with mitochondria:

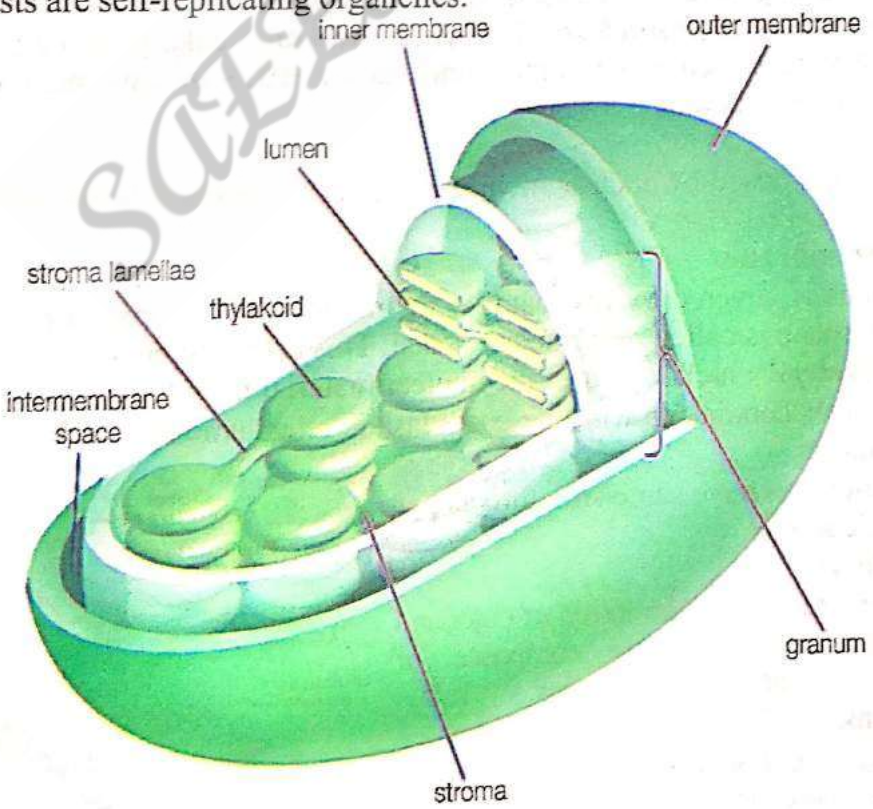
A. Replication of ATP synthase gene
B. Glycosylation of Albumin
C. Conversion of a hexose to triose
D. Porphyrin synthesis

PLASTIDS

- Plastids are membrane bounded; mostly pigment containing bodies present in the cells are called plastids.
- These are present in plant cells only.
- All types of plastids are formed from a precursor structure, called ***proplastids***.

Chloroplast

- These are green plastids, present in green parts of plants like leaves, woody stem and unripened fruit coverings.
- Chloroplasts vary in their shape and size with a ***diameter of 4-6 μm***.
- Under light microscope they are heterogeneous structures with small granules called grana embedded in the matrix.
- ***Envelop*** is double membrane covering.
- ***Stroma*** covers most of the volume of the chloroplast, contains proteins/enzymes required for the synthesis of carbohydrates during Calvin cycle. The most abundant and important enzyme is Rubisco. It also contains ***circular DNA*** and ***70S ribosomes***, so proteins are also synthesized here. Presence of these substances indicates that it is semi-autonomous organelle.
- ***Thylakoids*** are flattened vesicles which arrange themselves to form grana and inter-grana.
- ***Grana*** are piles of thylakoids stacked on each other like coins.50 or more thylakoids piled to form one granum. On these layers, chlorophyll molecules are arranged, thus appear green.
- ***Inter-grana*** are a non- green part which interconnects grana.
- Membranes of grana are sites where sunlight energy is trapped and ATP is formed.
- Chloroplasts are self-replicating organelles.



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Chromoplasts

- They impart colours to the plants other than green.
- They are present in the ***petals of the flowers and in the ripened fruit.***
- They help in ***pollination and dispersal of seeds.***

Leucoplasts

- They are ***colorless.***
- They are ***triangular, tubular*** or of some other shape.
- They are found in the ***underground parts*** of the plants and ***store food***, e.g. ***amyloplast*** which stores starch, ***elaioplast*** which stores lipids and ***proteinoplast*** which stores proteins.

CRITICAL THINKING

10. Ripening fruits softens due to:

A. Jelly formation in acidic pH
B. Conversion of starch into sugar
C. Solubilization of pectate of middle lamella
D. Incorporation of pectate in middle lamella

NUCLEUS

Introduction

- It is the most prominent and most important part of the cell, also called as brain of cell.
- They are visible only in non- dividing cells.
- In animal cell they are ***central*** in position with exception of skeletal muscle fiber.
- In plant cells they are pushed to ***periphery*** due to the presence of large vacuole.
- They may be ***irregular or spherical in shape.***
- A cell containing single nucleus is called ***mononucleate***, two as ***binucleate*** and with more than two as ***multinucleate.*** It is absent in some eukaryotic cells, such as mature phloem sieve tube elements in plants and mature RBCs of most mammals, hence these cells are calls ***anucleated.***

Structure

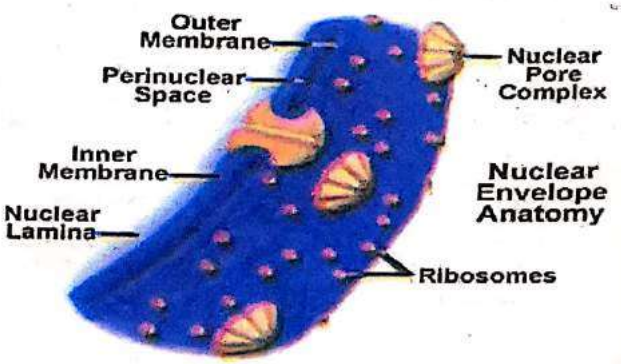
- Nucleus is composed of nuclear membrane, nucleoli, nucleoplasm and chromosomes or chromatin network.

A) Nuclear Membrane

- Each nucleus is covered by two parallel membranes with a space of 10-15 μm between them. This space is called peri-nuclear space. This arrangement of membrane is called as ***nuclear envelope*** which separates the nuclear material from the cytoplasm.
- The outer layer continuous with the endoplasmic reticulum and the inner one encloses the nuclear contents.
- These membranes have same structure as per fluid mosaic model.

B) Nuclear Pores

- Nuclear pores result from the fusion of outer and inner membranes. They are composed of specialized transport proteins called **nucleoporins.**
- They act as a ***gateway*** for the exchange of materials with the cytoplasm.



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- Their number is variable depending upon the differentiation of the cell i.e. undifferentiated cells like eggs have 30,000 pores / nucleus while erythrocytes, well differentiated cells have 3- 4 pores/nucleus.

C) Nucleoplasm

- It is transparent semi-fluid ground substance.
- It contains DNA, RNA, proteins, Mg^{+2} ions, free nucleotides and enzymes (DNA and RNA polymerase).

CRITICAL THINKING

11. Part of eukaryotic cell where formation and action of Primase takes place respectively:

A. Nucleoplasm & Cytoplasm
B. Cytoplasm & Nucleoplasm
C. Cytoplasm only
D. Nucleoplasm only

D) Nucleolus

- Nucleolus is non-membranous, darkly stained body within the nucleus, and may be one or more in the nucleus.
- It is usually attached to the chromatin at specific site called ***nuclear organizer region.***
- They appear during interphase & disappear during cell division.
- RNA (rRNA) is synthesized and stored in it.
- Nucleolus is composed of two regions: ***peripheral granular area*** containing precursors for ribosomal subunits and ***central fibril area*** containing rRNA and rDNA.
- It is the ***factory for ribosome synthesis***.

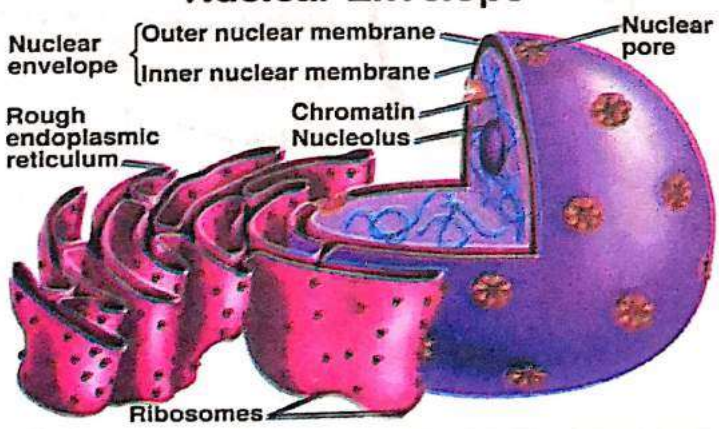
E) Chromatin & Chromosome

- Each chromosome is a thread like structure resulting from organization of chromatin material during cell division.
- Chemically chromosomes are composed of ***DNA and protein/histones***.
- Under compound microscope they appear to be made of arms (chromatids) and a centromere, the place where spindle fibers are attached during cell division.
- **Centromere*/primary constriction*** is the place on the chromosome and ***Kinetochore*** is a place on centromere where spindle fibers are attached during cell division.

Chromosome Number In Different Species

Species	Diploid (2n)	Haploid (n)	Species	Diploid (2n)	Haploid (n)
Man	46	23	Frog	26	13
Chimpanzee	48	24	*Drosophila*	8	4
Onion	16	8	Potato	48	24
Garden Pea	14	7	Pigeon	80	40

Nuclear Envelope



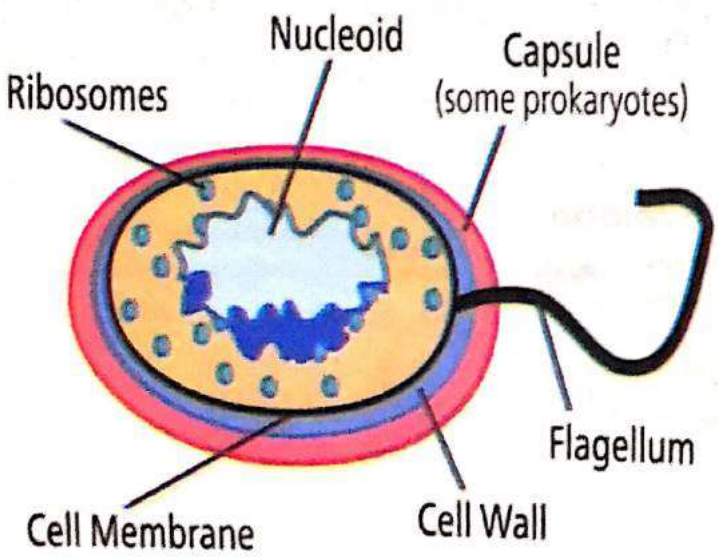
Functions

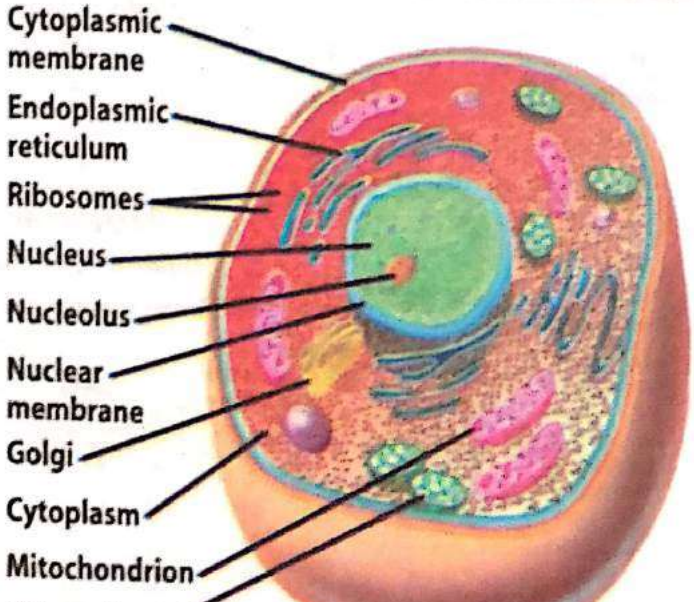
- It controls all the metabolic activities of cell.
- It has all the genetic information in a cell.

COMPARISON BETWEEN PROKARYOTIC AND EUKARYOTIC CELLS

Differences	Prokaryotic Cell	Eukaryotic Cell
Well Defined Nucleus	Absent	Present
DNA	Submerged in cytoplasm	Present in nucleus
Type of DNA	Circular DNA as nucleoid	Linear DNA in nucleus
Membrane Bounded Organelles	Absent	Present
Ribosomes	Small sized, 70S ribosomes (50S larger sub-unit and 30S smaller sub-unit)	Large sized, 80S ribosomes (60S larger sub-unit and 40S smaller sub-unit)
Cytoskeleton	Absent	Present
Cell Wall	Peptidoglycan/ Murein/ Sacculus	Cellulose/ Chitin
Cell Membrane	Sterols absent	Sterols present
Mesosomes	Present	Absent
Cell Division	Binary fission	Mitosis/ Meiosis
Histones	Absent	Present
Composition of Flagella	Flagellin	Tubulin
Example	Bacterial cell, Cells of blue green algae	Plant and Animal cells

Prokaryotes vs Eukaryotes





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TOPIC-5 » COORDINATION & CONTROL

COURSE CONTENT

- Steps Involved in Nervous Coordination
- Sensory Receptors and Their Working
- Neurons (Structure and Types)
- Reflexes and Reflex Arc
- Nerve Impulse
- Synapse
- Central Nervous System
- Brain
- Spinal cord
- Peripheral Nervous System
- Hormones-The Chemical Messengers
- Endocrine System of Man (Hypothalamus)
- Pituitary Gland
- Thyroid Gland
- Parathyroid Gland
- Pancreas
- Adrenal Glands
- Gonads
- Hormonal Feedback Mechanism

STEPS INVOLVED IN NERVOUS COORDINATION

In almost all the animals' coordination is executed via neuronal and chemical (endocrine) systems.

Neuronal Coordination

- This type of co-ordination involves specialized cells or ***neurons*** linked together directly or indirectly via the central nervous system, to form network that connects the cell or organs which receive stimuli and those which carry out actions or responses.
- The neurons have the capacity to generate and conduct impulses which travel across the synapse.
- Three basic components of nervous system are:

(i) Receptors
(ii) Neurons
(iii) Effectors

CRITICAL THINKING

1. **Pick the example of an effector:**
 A. Osmoreceptors
 B. G-cells
 C. Limbic system
 D. Ear

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Sensory Receptors and their Working

A cell or a neuron or a receptor organ which can detect changes in the external and internal environment of the animal is called a receptor.

Type	Sensation	Examples
Chemoreceptors	Smell, taste, blood CO_2, O_2, glucose, amino acids, fatty acids	Receptors in hypothalamus
Mechanoreceptors	Touch, pressure, hearing, equilibrium	Ear, skin, etc.
Photoreceptors	Light	Eyes (Rods and cone cells)
Thermoreceptors	Cold and warmth	Receptors in skin
Nociceptors	Pain	e.g., in skin

Working of Sensory Skin Receptors

- At least five different sensations are perceived by the skin, i.e., touch, pressure, heat, cold, and pain.
- There are at least three different types of sensory endings concerned with these sensations:

Receptor	Location	Structure	Sensation
Free Nerve Endings.	At the base of hair.	Free nerve endings.	Touch
Meissner's Corpuscles	In papillae which extend into ridges of the fingertips.	Specialized cellular encapsulated corpuscles, Spiral and twisted endings, each ending in a knob.	Touch
Pacinian Corpuscles	Deep in the body.	Encapsulated neuron endings. Mostly located in the limbs.	Deep Pressure stimuli, vibration sensations.

Distribution of Receptors in the Skin

- Receptors are not evenly distributed throughout the skin rather are located at the sites of specific function.
- Their relative abundance also varies e.g.
 Pain receptors 27 X > Cold receptors.
 Cold receptors 10 X > heat receptors.

NEURONS (STRUCTURE AND TYPES)

- It is the basic structural and functional unit of nervous system.
- Neurons can generate and conduct nerve impulses which travel across synapses and pass from receptors to effectors, bringing about nervous coordination.
- Neuroglia cells mostly present in higher animals, playing important role in nutrition of neurons and their protection by myelin sheath. They constitute nearly half of the nervous system.
- Neurons once matured do not divide any further. However, they exhibit limited regenerative capabilities, only if neural cell body is intact.

CRITICAL CONCEPT!

Inability of Neurons to Divide:
Neurons are unable to divide because they enter in G_0 phase permanently. Moreover, they lack centrioles thus unable to form mitotic apparatus.

Structure of Neuron

A typical neuron consists of:

(i) Cell body
(ii) Dendrites

(iii) Axons

Cell Body

- It is also called soma, is the ***chief nutritional part*** of the cell, and synthesizes materials necessary for growth and maintenance of neuron.
- It contains nucleus and other cellular organelles, like E.R, ribosomes, Golgi apparatus, mitochondria embedded in cytoplasm.
- ***Nissl's granules*** are group of ribosomes which are present in association with R.E.R.
- If it is intact, the neuron can regenerate its axonal and dendrital components.

Axons

- The processes ***carrying impulses away from cell body*** are called axons.
- Cellular organelles like mitochondria, microtubules and neurofibrils, R.E.R. and G.A are present throughout the axoplasm of the neuron.
- Most of the axons are surrounded by protective sheaths called ***myelin sheath***, important for neuronal nutrition, protection and proper propagation of impulses.

Dendrites

- These are processes that ***carry impulses towards the cell body.***
- These are usually thin fibres devoid of Schwann cells and thus non-myelinated.
- They unlike axon give a ***spiny look.***

Myelin Sheath

- Neurons are surrounded by a layer, of fatty substance, called myelin sheath.
- It acts as insulator and gives white appearance.
- It is secreted by Schwann cells in peripheral nervous system.

Types of Neurons

There are three main types of neurons:

(i) Sensory Neurons

- Sensory neurons carry sensory information from receptors to associative neurons present in CNS.
- The dendrite endings of some sensory neurons also act as receptors.
- They usually have single long dendrite called Dendron. It is structurally and functionally similar to axon.

(ii) Associative Neurons

- Associative (intermediate/ relay / inter) neurons are present in CNS and connect sensory and motor neurons.
- They are involved in processing and interpretation of information coming from receptors.

CRITICAL THINKING

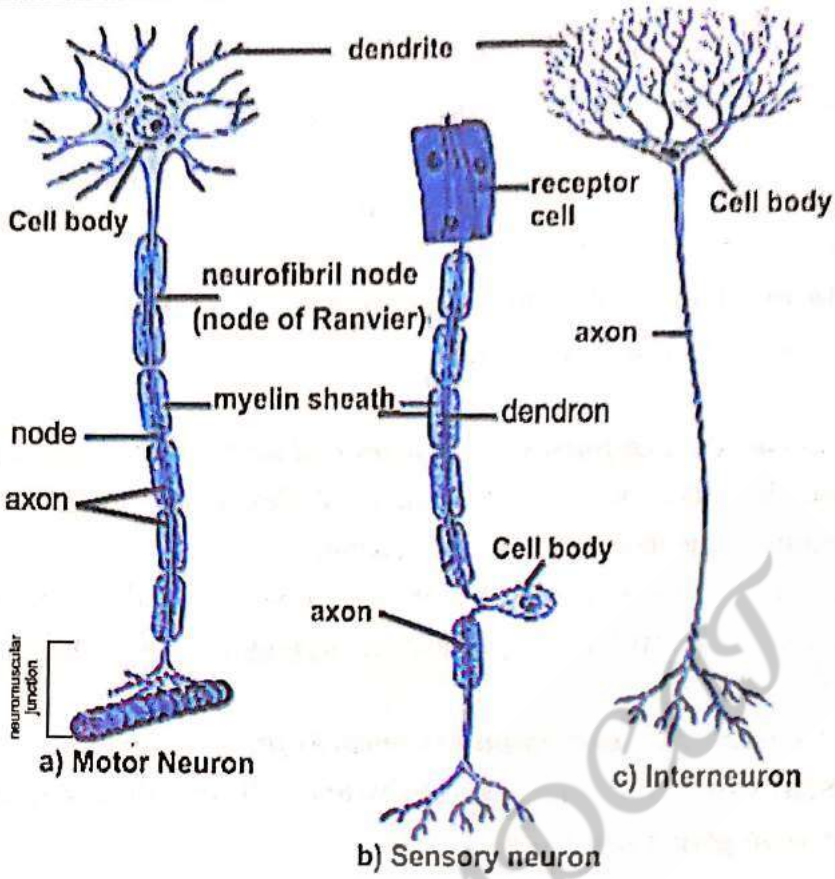
2. Most of the brain tumors are caused by the uncontrolled mitotic divisions of:

A. Neurons
B. Neuroglial cells
C. Schwann cells
D. Leydig cells

(iii) Motor Neurons

- Motor neurons carry the information from relay neurons to effectors.

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REFLEXES AND REFLEX ARC

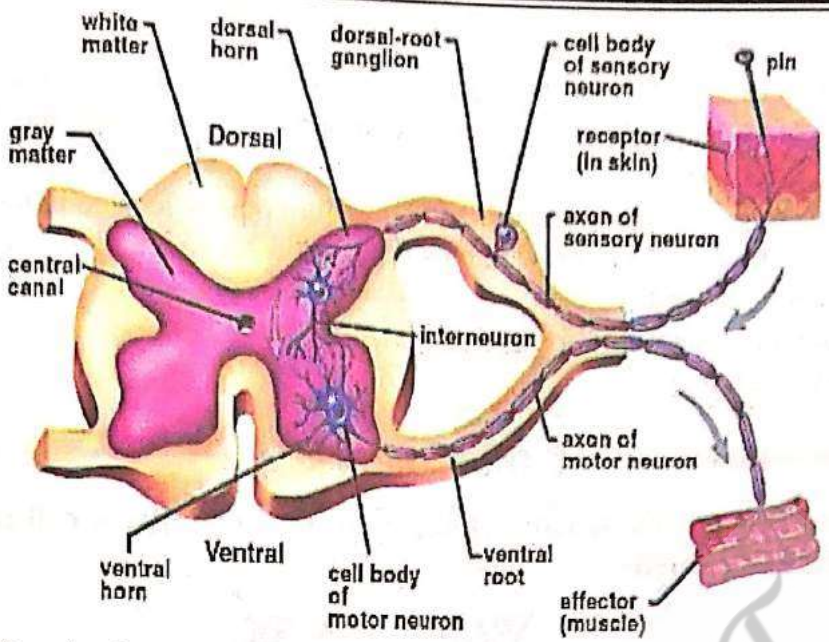
CLASSIFICATION OF REFLEXES

- There are several ways to classify the reflexes of the body. Following are the classification of reflexes.
- **Based on the Type or Function**: This is based on the movement of the organs or parts of the body that move due to the reflex. Some reflexes that move the skeletal muscles are extensor, flexor, locomotor and statokinetic. Reflexes that involve the function of internal organs include cardiovascular, digestive, secretory and excretory.
- **Based on the Degree of Complexity:** Reflexes can also be classified based on the degree of complexity of the neuron or nerve organization within the reflex arcs. Under this category, these can be monosynaptic or monosegmental reflexes that involve only one segment of the central nervous system and multisynaptic or intersegmental reflexes that involve more than one segment of the central nervous system.
- **Based on the Development**: Reflexes can be innate reflexes and acquired reflexes where the former includes genetically determined and the latter type includes learned reflexes.
- **Based on the Response:** Reflexes can be somatic reflexes that control skeletal muscle contractions and include superficial and stretch reflexes; the other one includes visceral or autonomic reflexes.

REFLEX ACTION AND REFLEX ARC

- Reflex action is a type of involuntary action.
- Reflex arc is the pathway of the passage of impulse during a reflex action.
- It includes:

 Receptors → Sensory neuron → Intermediate neurons → Motor neurons → Effectors → Brings about the desired action.



Importance of Reflex Action

It helps an animal to save himself from danger e.g. when a person steps on a sharp object this message is immediately conveyed by the pain receptors to the spinal cord which results in contraction of the muscles of the leg and immediate withdrawal of the leg.

NERVE IMPULSE

Definition

Nerve impulse is a wave of electrochemical changes, which travels along the length of neurons involving movement of ions across the membrane and chemical reactions.

Membrane Potential

- Electrical potential is the measure of the capacity to do electric work.
- The electrical potential that exists across a cell membrane is called membrane potential.

(i) Resting Membrane Potential

- Potential difference across the membrane when neuron is in ***non-conducting state*** is called resting membrane potential (RMP).
- Neuron in this state is in ***polarized form***.
- A typical neuron at rest is ***more positive electrically outside*** than inside the cell membrane.
- Its value for a typical neuron is ***-70 mV***.

(ii) Active Membrane Potential/ Action Potential

- Potential difference across the membrane when neuron is in conducting state is called active membrane potential (AMP).
- It is in form of nerve impulse. During this state, inner membrane surface becomes more positive than outside.
- Its value is ***+50 mV***.

Ions Involved

- Na^+ and K^+ are most important in nerve cell and surrounding fluid.
- Na^+ is tenfold higher in concentration outside than inside the membrane surface.
- K^+ is twenty times more concentrated inside than outside.
- The large negative organic molecules/ions (such as proteins, organic acids etc.) are much more inside the membrane than outside. This makes the inside of neuron membrane more negative.

Channels Involved

- The cell membrane is virtually impermeable to all ions except K^+ so some K^+ leak out of the cell. The loss of these positive ions from neuron by diffusion accounts for more negative charges inside than outside.
- All the neurons have very active sodium and potassium pumps located in their cell membranes. Driven by the splitting of ATP, these pumps transport 3 Na^+ out and 2 K^+ into the cell, against their concentration gradient.
- Cell membrane has sodium and potassium gates which when open allow movement of ions along the concentration gradient.

CRITICAL THINKING?

3. **At which place of this neuron, changes in permeability of cell membrane can be calculated/detected?**



4. **Leakage of positive ions across the cell membrane occurs by:**

A. Active transport B. Osmosis
C. Passive transport D. Diffusion

Initiation of Nerve Impulse

- Under normal conditions, a nerve impulse is initiated by an appropriate stimulus (threshold stimulus) applied at one end of neuron.
- Minimum intensity of stimulus that is required to initiate a nerve impulse is called **threshold stimulus.**
- It results in a remarkable localized change in the resting membrane potential. It disappears for a brief instant and is replaced by action potential. This change is so brief (for a millisecond) that only a portion of neuron is in active state.

Conduction of Nerve Impulse (RMP → AMP)

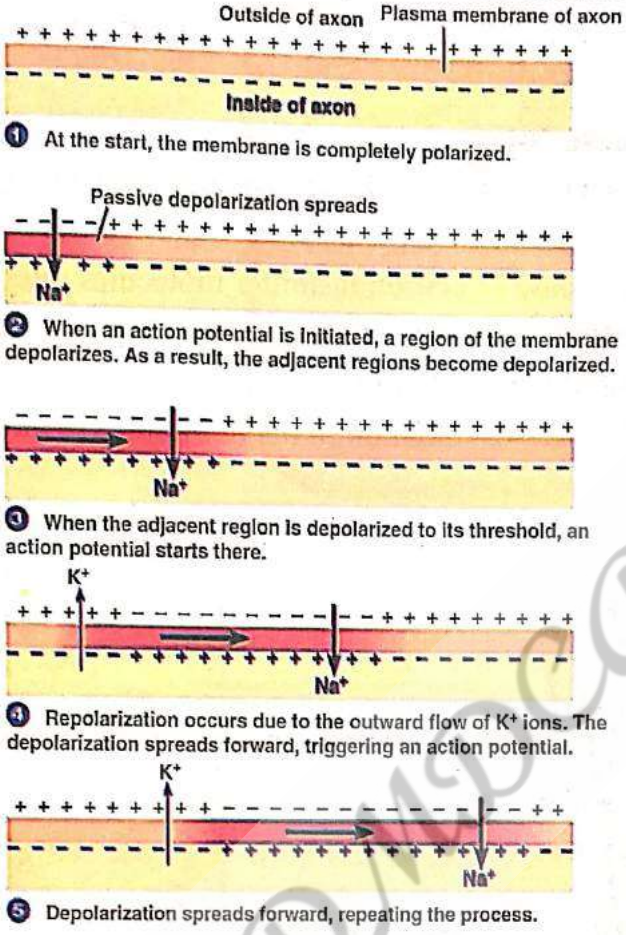
- The passage of nerve impulse is associated with increase in permeability of Na^+ moving inwards upsetting the potential momentarily, making the inside more positive than outside.
- This increased permeability is due to opening of sodium gates. When these gates open, Na^+ rush into the neuron by diffusion. Some K^+ moves out.
- The inner side of the cell membrane has excess of positive ions and outer surface becomes more negative.
- During active membrane potential, the neuron conducts the impulse in the form of nerve impulse.
- These changes occur along the length of neuron till the impulse reaches synapse.
- Soon after the passage of impulse, the resting membrane potential is restored by the movement of a small number of ions especially K^+ moving out. This neuron is now ready to conduct another impulse.

Repolarization of Neuron (AMP → RMP)

- It is the restoration of resting membrane potential, after the wave of depolarization has passed.
- Results from closure of Na^+ gates and opening of K^+ gates, without flux of K^+ ions, causing repolarization.

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- Na^+/ K^+ pump restore the original ionic gradient and thus the resting potential.
- The whole process of depolarization and repolarization takes about 2- 3 millisecond



Speed of Nerve Impulse

- Normal speed in humans is 100 m/s but can reach upto 120 m/s.
- The nerve impulse is conducted from node to node in jumping manner. This kind of jumping nerve impulse is called ***saltatory impulse***.

SYNAPSE

- Cytoplasmic gaps between consecutive neurons are called ***synapse***.
- A single neuron may form synapses with many incoming fibres of different neurons.
- A single nerve impulse does not necessarily get across the synapse. It may take two or three impulses arriving in rapid succession or perhaps simultaneously from two or more fibers to start an impulse in the next neuron.

Neurotransmitters

- The action potential cannot jump from one neuron to the next in line; rather the message is transmitted across synapse in the form of chemical messenger called neurotransmitters.

CRITICAL CONCEPT!

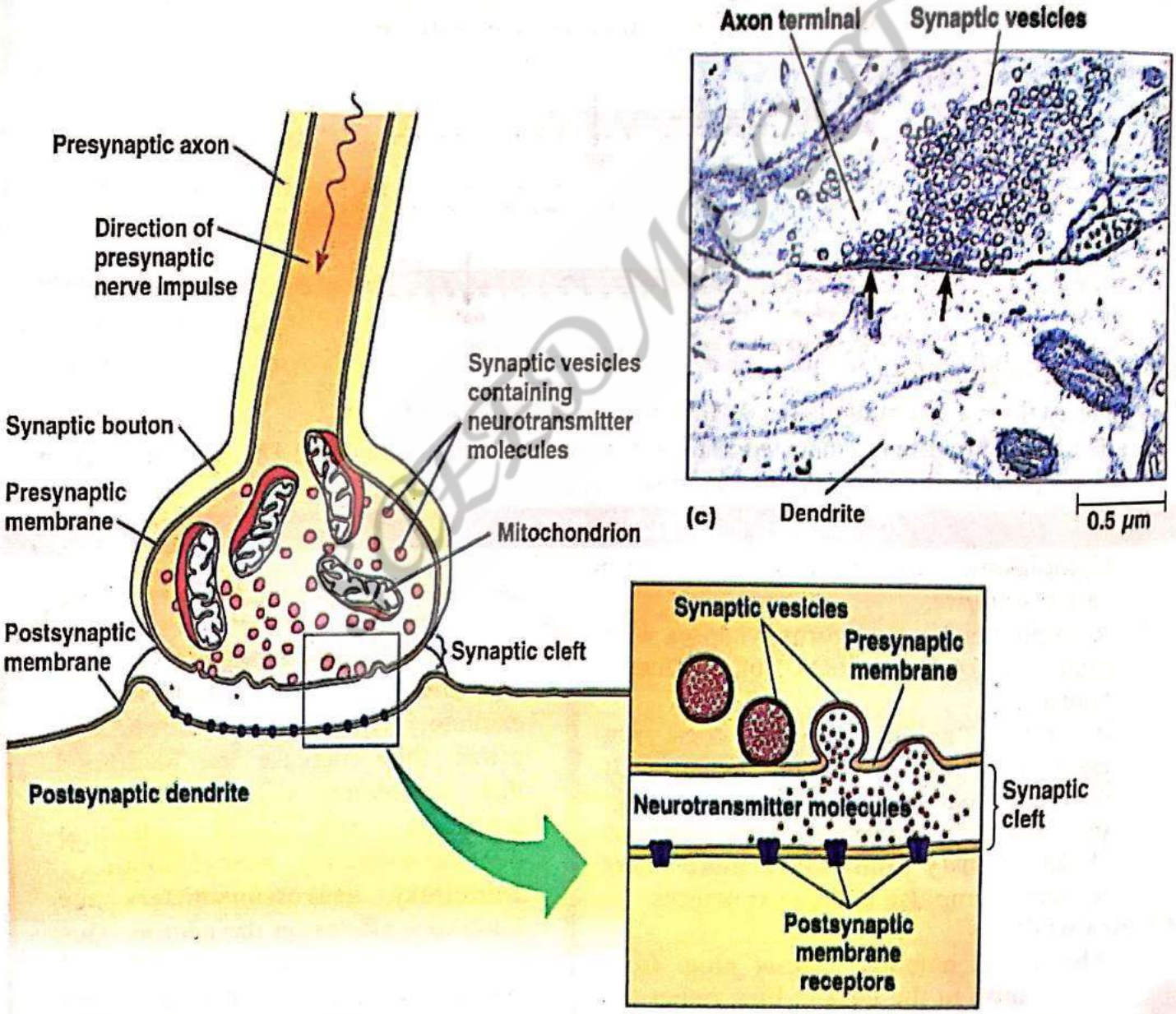
Type of Neurotransmitter:
Excitatory neurotransmitters have excitatory effects on the neuron. This means they increase the likelihood that the neuron will fire an action potential and will undergo depolarization, e.g., Acetylcholine.
Inhibitory neurotransmitters have inhibitory effects on the neuron. This means they decrease the likelihood that the neuron will fire an action potential, e.g., Dopamine and GABA.

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- Neurotransmitters are chemicals, which are released at the axon ending of the neurons at synapse.
- ***Acetylcholine*** is neurotransmitter for synapse outside CNS while adrenalin, nor-epinephrine, serotonin and dopamine in CNS.

Mechanism of Synaptic Transmission

- When an impulse reaches a synaptic knob, synaptic vesicles within it fuse with the pre-synaptic membrane.
- These vesicles cause release of neurotransmitter molecules into the ***synaptic cleft***.
- Neurotransmitter molecules bind to the receptors on post-synaptic membrane, causing changes in its permeability to certain ions.
- Change in permeability causes initiation of nerve impulse in the post-synaptic neuron.



There are two types of synapses;

(i) Electrical synapses

(ii) Chemical synapses

Electrical synapses

- In electrical impulse, which are specialized for rapid signal transmission, the cells are separated by a gap, the synaptic cleft, of only 0.2nm, so that an action potential arriving at the pre synaptic side of cleft, can sufficiently depolarize the post synaptic membrane to directly trigger its action potential.

Chemical synapses

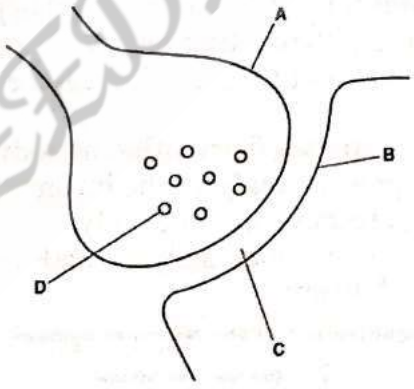
- The majority of synapses are chemical synapse where synaptic cleft has gap of more than 20nm.
- Through these synapses, information of impulse from one neuron is transmitted to another by means of chemical messengers, the neurotransmitters.

CRITICAL CONCEPT!

Electrical synapse:
In an electrical synapse, the presynaptic and postsynaptic membranes are very close together and are actually physically connected by channel proteins forming gap junctions. Gap junctions allow current to pass directly from one cell to the next. In addition to the ions that carry this current, other molecule, such as ATP, can diffuse through the large gap junction pores.

CRITICAL THINKING

5. **Nervous coordination transfer of nerve impulse from one cell to another. Which option shows site for binding of chemicals involved in chemical synapse?**



CENTERAL NERVOUS SYSTEM

- The human nervous system consists of **central nervous system (CNS)** and **peripheral nervous system (PNS).**

i. The **CNS** is a coordinating center and it lies in the midline of the body.
ii. Whereas, the **PNS** transmits information from receptors to CNS and transmit orders and commands from CNS to effectors.

ARCHIECTURE OF BRAIN & SPINAL CORD AND THEIR FUNCTIONS

Central Nervous System

Components of CNS

Central nervous system consists of brain and spinal cord, and both are hollow.

Protection of CNS

i. Meninges

The brain and spinal cord are covered with three protective membranes called meninges. The three meninges are

- Dura matter (next to the cranium).
- Arachnoid matter (middle membrane)
- Pia matter (next to the nervous tissue)

ii. Cranium & Vertebral Column

- Brain is enclosed within the cranium while spinal cord is enclosed within vertebral column.

iii. Cerebrospinal Fluid

- Between the arachnoid and pia matter there is a fluid, the cerebrospinal fluid (CSF), which helps to cushion the brain from shock.

CRITICAL CONCEPT!

Meninges:
Meninges are the three membranous envelopes pia mater (innermost), arachnoid mater, and dura mate (outermost), that surround brain and spinal cord. Cerebrospinal fluid fills the ventricles of the brain and the space between the pia mater and the arachnoid. The primary function of the meninges and of the cerebrospinal fluid is to protect the central nervous system.

BRAIN

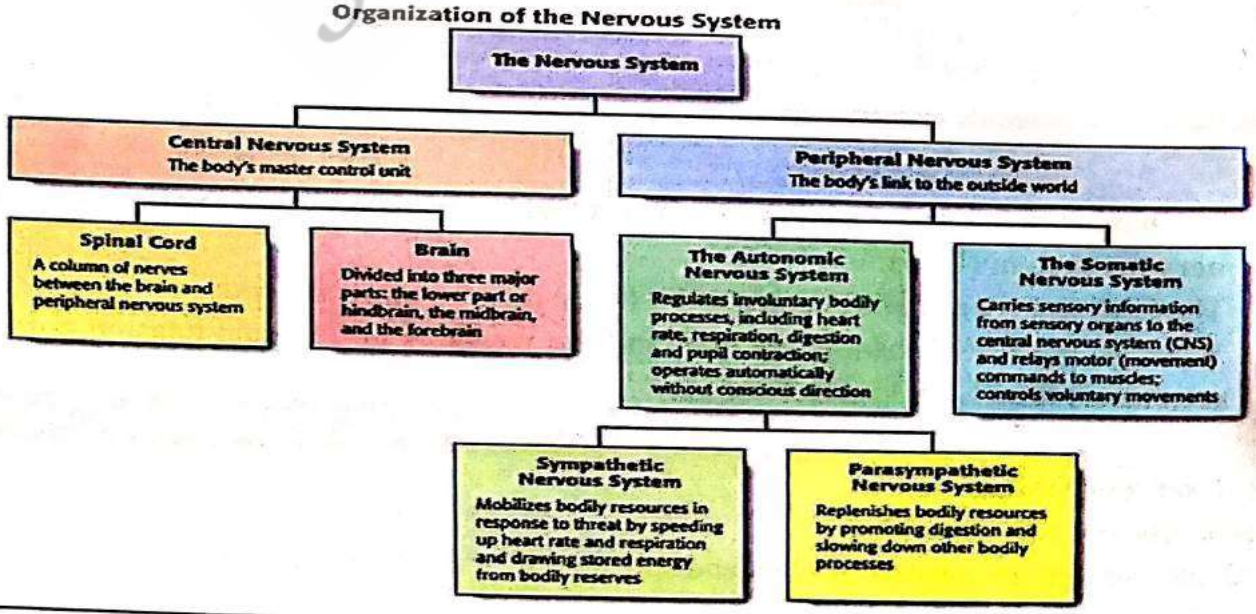
The brain is divided into three parts;

A) Forebrain

Forebrain consists of;

a. Cerebrum

- It is the largest part of the human brain.
- Cerebrum is divided into two **cerebral hemispheres** which are interconnected with each other by a band of axons, called **corpus callosum**.
- Each hemisphere contains four surface lobes: frontal, parietal, temporal and occipital lobe.
- Each lobe further contains different functional areas e.g., auditory (hearing) visual area etc.
- Each functional area consists of three sub-areas i.e., **sensory area, association area** and **motor area**.
- **Sensory area** receives impulses from different body parts.
- **Association area** interprets or analyzes the incoming information.
- The **motor area** control responses of the body.
- Cerebrum also functions in the analysis and interpretation of memory, reasoning, judgement, thoughts and dreams.

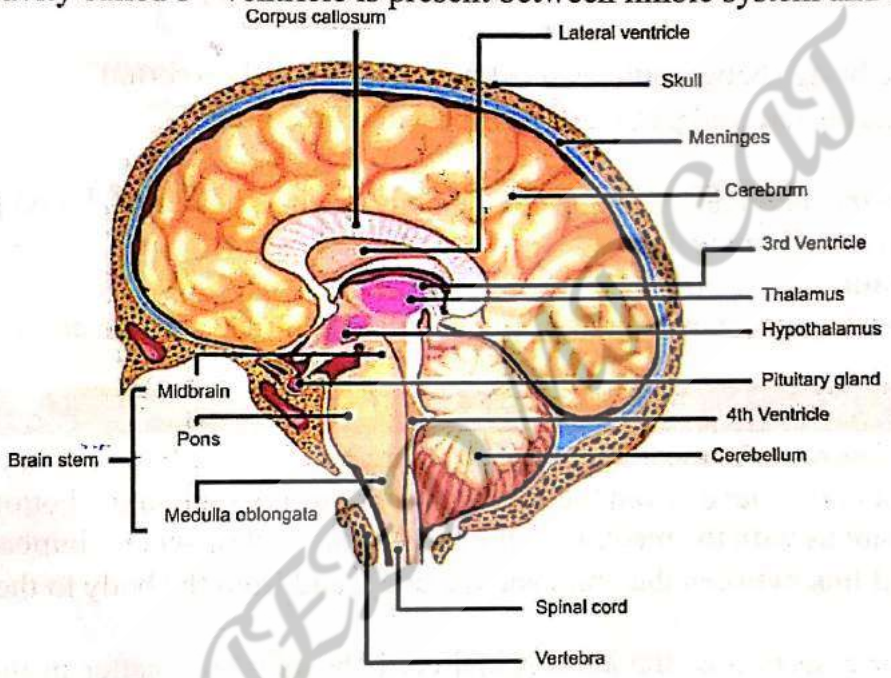


b. Thalamus

- It is below the cerebrum.
- It receives all sensory impulses (except sense of smell) and channels them to limbic system and to appropriate regions of the cortex for interpretation.

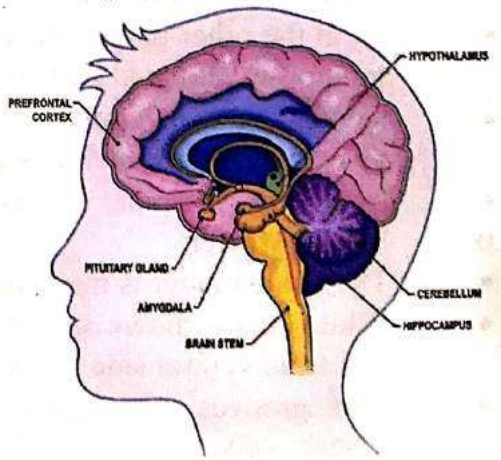
c. Limbic System

- The limbic system is a complex set of structures that lies on both sides of the thalamus, just under the cerebrum.
- It includes the **hypothalamus,** the **hippocampus,** the **amygdala**, and several others **nearby areas**.
- Between limbic system and cerebrum, two ventricle (cavities) are present which are commonly known as lateral ventricles or 1st and 2nd **ventricles**.
- Another cavity called 3rd ventricle is present between limbic system and thalamus.



(i) Hypothalamus

- On the ventral side of the thalamus is the hypothalamus.
- It maintains homeostasis and contains centres for regulating hunger, sleep, thirst, body temperature, water balance and blood pressure, menstrual cycle and sleep wake cycle.
- The hypothalamus also controls the pituitary gland and thereby serves as link between the nervous and endocrine system.



(ii) Amygdalae

- The amygdalae (Sing. amygdala) are two almond-shaped masses of neurons on either side of the thalamus at the lower end of the hippocampus.
- They control feeling and emotions of love, hate, anger, fear, rage and sexual arousal.

(iii) Hippocampus

- The hippocampus consists of two "horns" that curve back from the amygdala.
- It appears to be very important in converting things that are "in your mind" at the moment (in short-term memory) into things that you will remember for the long run (long-term memory).

B) Midbrain

- It is reduced in humans. It acts as a relay station for tracts passing between the cerebrum and the spinal cord or cerebellum.
- Midbrain contains **reticular formation**, which is a relay center connecting hindbrain with forebrain.

C) Hindbrain

Hindbrain consists of;

a. Cerebellum

- It controls equilibrium i.e., body position and coordination of the actions of individual muscles to produce complex activities such as walking, running, riding bicycles, doing delicate work with hand.
- The cerebellum is also involved in learning memory storage for behavior.

b. Pons

- It acts as a bridge between the cerebellum, medulla and cerebrum.
- It also controls rate and pattern of heartbeat and breathing.

c. Medulla

- It controls the automatic functions of the body, such as heartbeat, blood pressure, respiration, swallowing etc.

Ventricles of Brain

- Brain is hollow structure as it has cavities called ventricles. There are four ventricles in the brain.

SPINAL CORD

- The spinal cord is the most important structure between the body and the brain.
- The spinal cord extends from the **foramen magnum** (a hole in the bottom of skull) where it is continuous with the medulla to the level of the first or second lumbar vertebrae.
- It is a vital link between the brain and the body, and from the body to the brain.

Structure

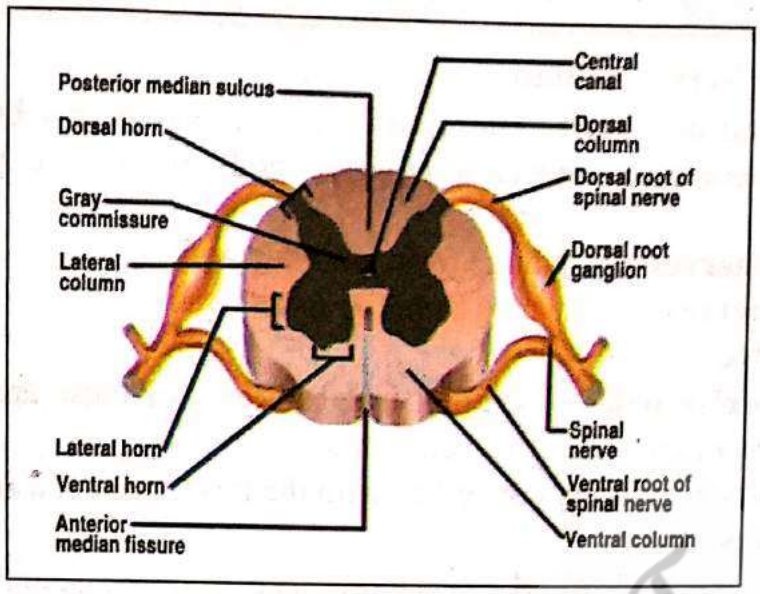
- A transverse section of the adult spinal cord shows white matter in the periphery, grey matter inside, and a tiny central canal filled with **CSF** at its center.

a. Grey Matter

- Grey matter is shaped like the letter "H" or a "butterfly". The two "wings" of the butterfly are connected across the midline by the dorsal grey commissure and below the white commissure.
- As in the other part of the nervous system, the grey matter consists of neuron cell bodies and non-myelinated parts of the fibres.
- Several pairs of spinal nerves originate from **ventral horn** of grey matter. Similarly, several pairs of spinal nerves join the spinal cord through dorsal horn of grey matter.
- Dorsal root of spinal nerves, also contain ganglia present just beside the spinal cord.

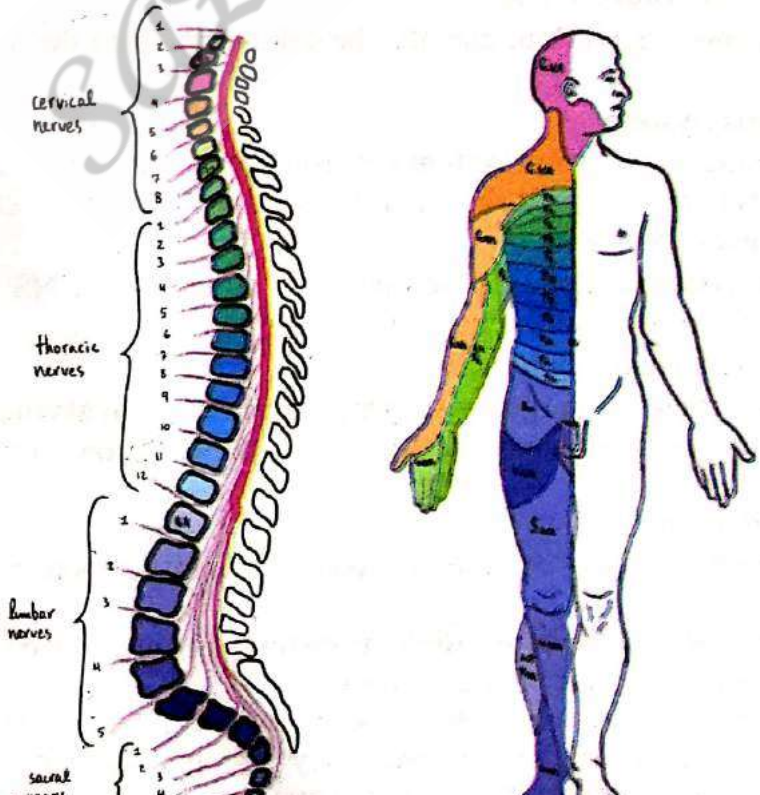
b. White Matter

- The white matter is made up of bundles of myelinated fibres.
- White matter shows deep grooves from both side i.e., from dorsal side to the central canal and from ventral side to the **central canal**.
- The grooves are called **posterior median sulcus** and **anterior median sulcus** respectively.



c. Segments of Spinal cord

- The spinal cord is divided into four different regions: the cervical, thoracic, lumbar and sacral regions.
- The different cord regions can be visually distinguished from one another. Two enlargements of the spinal cord can be visualized: The cervical enlargement, which extends between C3 to T1; and the lumbar enlargements which extends between L1 to S2.
- The cord is segmentally organized. There are 31 segments, defined by 31 pairs of nerves exiting the cord. These nerves are divided into 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal nerve. Dorsal and ventral roots enter and leave the vertebral column respectively through intervertebral foramen at the vertebral segments corresponding to the spinal segment.



PERIPHERAL NERVOUS SYSTEM

Cranial and Spinal Nerves in Man

- The peripheral nervous system consists of the nerves that branch out from the central nervous system and connect it to other body parts. The peripheral nervous system includes;

1. The **cranial nerves** which arise from the brain and;
2. The **spinal nerves**, which arise from the spinal cord.

A. Cranial nerves

- There are **twelve pairs of cranial nerves.** Some of these are sensory nerves, some are motor nerves and others are mixed nerves.
- Cranial nerves are largely concerned with the head, neck and facial regions of the body.

B. Spinal nerves

- **Thirty-one pairs of spinal nerves** originate from the spinal cord. They are all mixed nerves, and they provide two-way communication between the spinal cord and parts of the arms, legs, neck and trunk.
- Each spinal nerve emerges from the spinal cord by two short branches or roots, which lie within the vertebral column.

a. Dorsal root

- The dorsal root contains the fibres of sensory neuron, which conduct impulses to the spinal cord.

b. Ventral root

- The ventral root contains the fibres of motor neurons, which conduct impulses away from the cord.
- The two roots join just before a spinal nerve leaves the vertebral column. Each spinal nerve serves the particular region of the body in which it is located.

Somatic and Autonomic Nervous System

- The **peripheral nervous system** can also be subdivided into the somatic and autonomic nervous systems.

I. Somatic Nervous System

- Generally, the **somatic nervous system** consists of the cranial and spinal nerve fibres that connect the CNS to the skin and skeletal muscles; it is involved in conscious activities.

II. Autonomic Nervous System

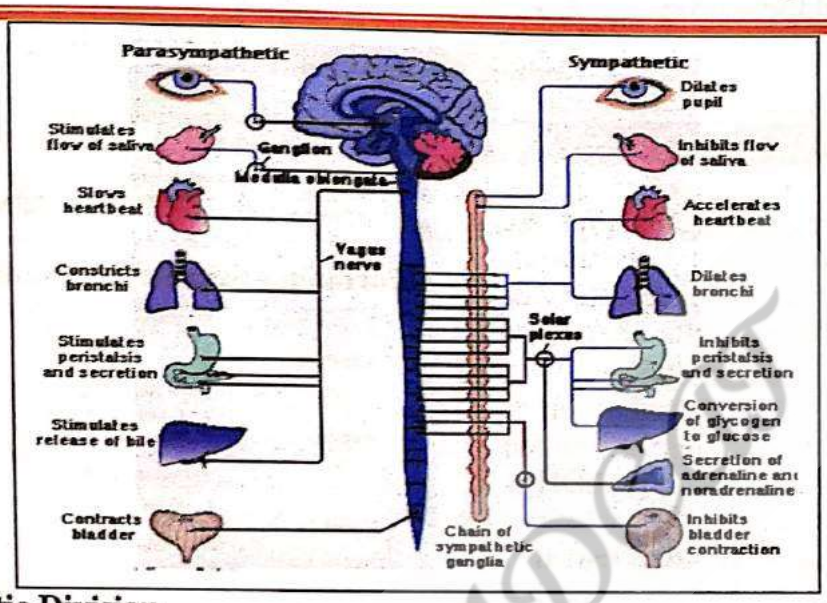
- The **autonomic system** includes those fibres that connect the CNS to the visceral organs, such as the heart, stomach, intestines and various glands.
- It is concerned with unconscious activities.
- The autonomic system is divided into **sympathetic** and **parasympathetic system**. Both of these systems function automatically and usually subconsciously in an involuntary manner.

a. Sympathetic Division

- The **sympathetic division** controls various autonomic functions during the state of emergency.
- It prepares the body for **fight or flight response**. In times of danger, the sympathetic system prepares the body for violent activity.
- It consists of only spinal nerves that arise from first thoracic segment (T1) to second lumber segment (L2) of the spinal cord. They pass into sympathetic ganglia which are organized into two chains that run parallel to and on either side of the spinal cord.

CRITICAL THINKING?

6. **Retention of urine in bladder in adults is under control of:**
 A. Somatic nervous system
 B. Autonomic nervous system
 C. Sympathetic nervous system
 D. Parasympathetic nervous system



b. Parasympathetic Division

- A few cranial nerves, including the **vagus nerve**, together with fibres that arise from the sacral portion of the spinal cord, form the **parasympathetic division**.
- It controls various autonomic functions during the **state of rest**. In short, the parasympathetic system returns the body functions to normal after they have been altered by sympathetic stimulation.
- The parasympathetic system reverses the changes when the danger is over.

HORMONES-THE CHEMICAL MESSENGERS

- Hormones are organic compounds of *varying structural complexity*.
- They are poured directly and are transported to the blood to respective target cells/tissues
- They ***do not initiate new biochemical reactions*** but produce their effects by regulating enzymatic and other chemical reactions already present.
- They may either stimulate or inhibit a function.
- Hormones may also control some long-term changes, such as rate of growth, rate of metabolic activity and sexual maturity.

CRITICAL CONCEPT!

Mechanism of Hormonal Action:
Hormone does not act on the target cell directly. It combines with receptor to form hormone-receptor complex. This complex executes the action through one of the following mechanisms:
1. By altering permeability of cell membrane
2. By activating intracellular enzyme
3. By acting on genes

CRITICAL CONCEPT!

Portal System:
Portal system can be defined as a part of the systemic circulation, in which blood draining from the capillary bed of one structure flows through larger vessels to supply the capillary bed of another structure, before returning to the heart.

Types of Hormones

- Chemically hormones may be of following four types:

Category	Gland	Hormones
Protein	Islets of Langerhans	Insulin, Glucagon
Polypeptides	Posterior pituitary	ADH, Oxytocin
Amino Acids and Derivatives	Thyroid, Adrenal Medulla	T3, T4, Epinephrine, Nor-epinephrine
Steroid	Gonads, Adrenal Cortex	Estrogen, Testosterone, Cortisone.

ENDOCRINE SYSTEM OF MAN (HYPOTHALAMUS)

Glands

- These are the organs that are specialized for secretions. Glandular cells are secretory or neurosecretory cells that have abundant Golgi bodies.
- Hormones released from neurosecretory cells are called as neuro-secretions e.g. ADH is neuropeptide.
- Glands can be divided into two main categories i.e. exocrine and endocrine glands.
- Endocrine system of human consists of about 20 endocrine glands.

CRITICAL CONCEPT!

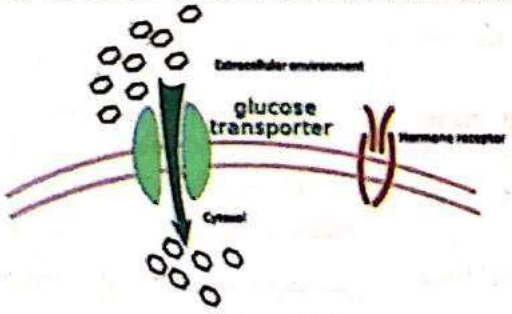
Hormones Secreted by Some Other Organs:

Pineal gland	Melatonin
Thymus	1. Thymosin 2. Thymin
Kidney	1. Erythropoietin 2. Thrombopoietin 3. Renin 4. 1,25-dihydroxycholecalcifero (calcitriol) 5. Prostaglandins
Heart	1. Atrial natriuretic peptide 2. Brain natriuretic peptide 3. C-type natriuretic peptide
Placenta	1. Human chorionic gonadotropin (HCG) 2. Human chorionic somatomammotropin 3. Estrogen 4. Progesterone

Feature	Exocrine Glands	Endocrine Glands
Another Name	Ducted glands	Ductless glands
Secretions	Enzymes, mucus etc.	Hormones
Transportation	Through ducts	Through blood
Examples	Sweat glands, Salivary glands	Adrenal glands, Pituitary gland

CRITICAL THINKING?

7. A hormone has bound to its receptor embedded in membrane of its target cell. Movement of glucose into cell as a result of hormone binding to its receptor is:



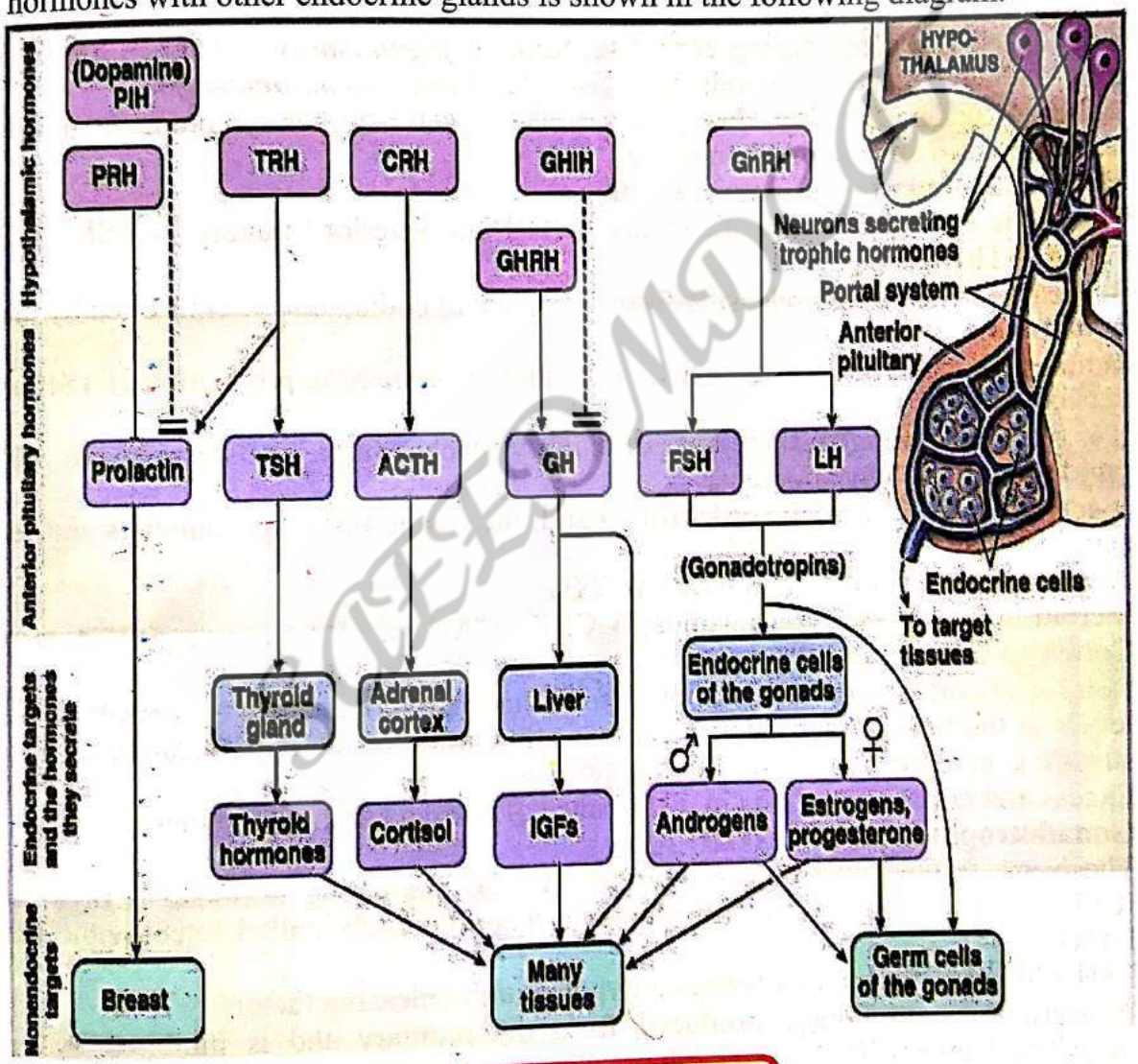
A. Facilitated diffusion
B. Diffusion
C. Active transport
D. Passive transport

8. Which of the following will not take place as a result of hormone binding to its receptor? (see above diagram)

A. Increased glycolysis
B. Decreased glycogenolysis
C. Increased gluconeogenesis
D. Decreased lipolysis

Hypothalamus

- It is a part of forebrain. It has neurosecretory cells which produce and secrete a variety of hormones.
- It is here that many of the sensory stimuli of nervous system are converted into hormonal responses.
- It is believed that ***oxytocin*** and ***ADH*** are produced in hypothalamus and travel down the nerves to the posterior lobe of pituitary to be stored in nerve endings. They are released from posterior pituitary after receiving nerve impulses from the hypothalamus.
- Another cluster of neurons in hypothalamus produce and secrete a battery of releasing and inhibiting hormones, which are carried by the blood to the anterior pituitary. These regulate the secretion of many tropic hormones, growth hormones and prolactin, manufactured by the anterior pituitary cells. The integration of hypothalamus through its hormones with other endocrine glands is shown in the following diagram.



CRITICAL THINKING

9. Portal system is not associated with which of the following organs/tissues?

A. Nephrons
B. Liver
C. Pituitary
D. Alveoli

PITUITARY GLAND

- In man, the pituitary gland or hypophysis cerebri is an ovoid structure about 0.5gm in the adult and is connected to brain through a short stalk (the infundibulum).
- It has three lobes viz, anterior, median and posterior.
- The anterior lobe is often referred to as the ***master gland***, because in addition to producing primary hormones it produces the tropic hormones which control the secretion of hormones in many of the other endocrine glands.

Anterior Lobe

(i) Somatotrophin Hormone (STH)

- It is also called as growth hormone.
- Hypothalamus → SRF → Anterior Pituitary → STH → Growth
- Somatotrophin releasing factor (SRF) is secreted from hypothalamus throughout life.
- When growth has mostly ceased after adolescence, the hormone continues to promote protein synthesis throughout the body.
- If produced in excess during early life, leads to ***gigantism*** or if later in life causes the abnormal development of hands, feet, jaws etc. (known as ***acromegaly***).
- If there is under secretion, ***dwarfism*** results, as well as other symptoms associated with lack of thyroid and adrenal hormone.

(ii) Thyroid Stimulating Hormone (TSH)

- Thyroxine in Blood → Hypothalamus → TRF → Anterior Pituitary → TSH → Thyroid Gland →Thyroxine
- Release of thyrotrophin releasing factor from the hypothalamus is controlled by the levels of thyroxine in the blood.
- In the presence of low levels of thyroxine, there is increasing production of TSH and vice versa.
- It is secreted throughout life but particularly reaches high levels during the periods of rapid growth and development.
- It acts directly on the cells of thyroid gland, increasing both their numbers and secretory activity.

(iii) Adrenocorticotrophic Hormone (ACTH)

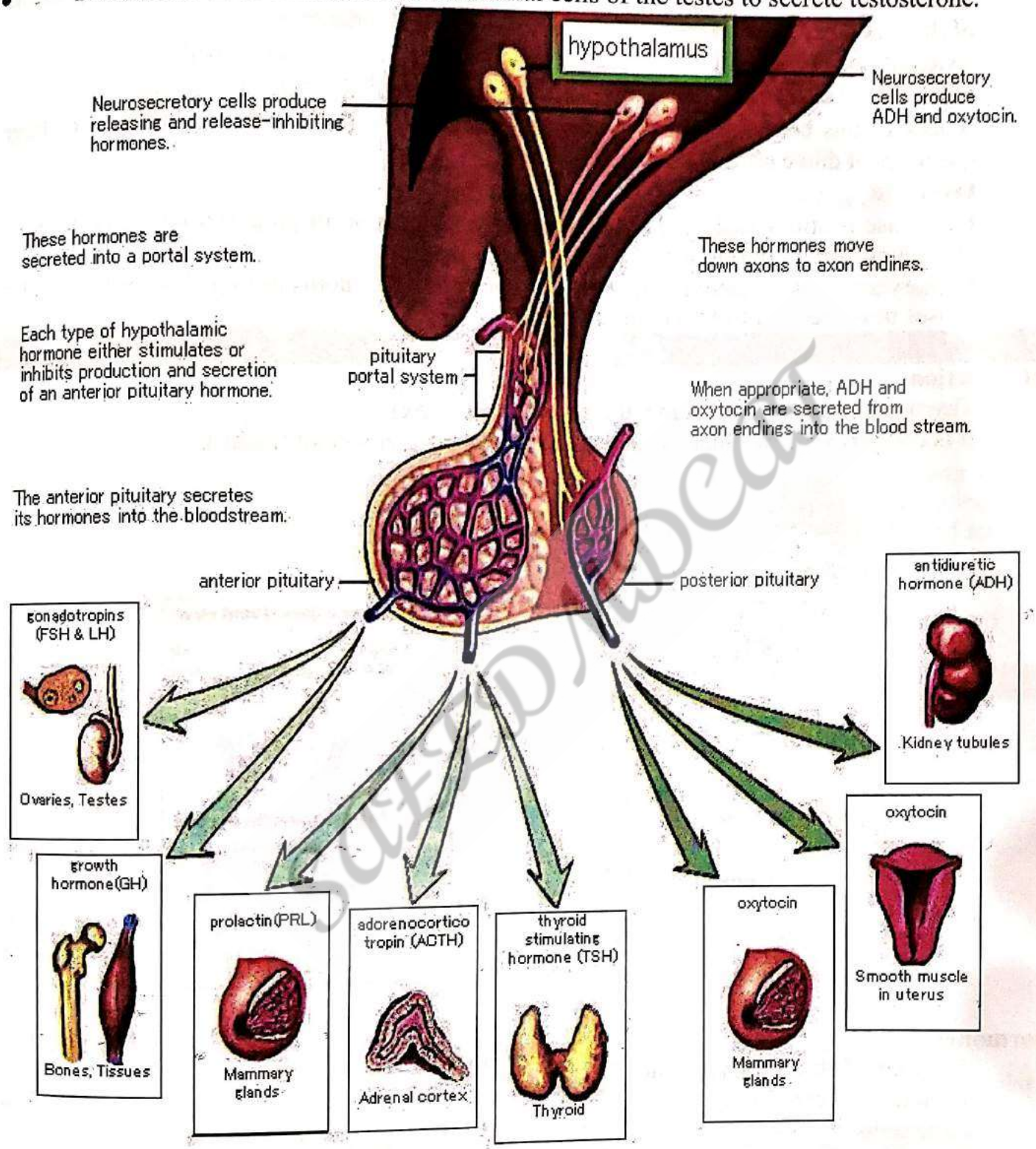
- Steroid in Blood → Hypothalamus → CRF → Anterior Pituitary → ACTH → Adrenal Cortex → Corticosteroid
- Release of corticotrophin releasing factor from the hypothalamus is controlled by steroid levels in the blood and by direct nervous stimulation of the hypothalamus as a result of stress e.g. cold, heat, pain, fright, infections.
- Excess and deficiency results in disturbance of normal adrenal functions

(iv) Gonadotrophic Hormone (GH)

- These are follicle stimulating hormone (FSH), luteinizing hormone (LH, also called ICSH in male) and prolactin (sometimes inappropriately called luteotrophic hormone, LTH).
- FSH and LH/ICSH share a common hypothalamic releasing factor.
- Prolactin is continuously produced from the pituitary and is inhibited by prolactin inhibiting factor (PIH) from the hypothalamus.
- Prolactin stimulates milk production and acts with LH.
- FSH in females stimulates follicle development and secretion of estrogen from the ovaries; in males it stimulates development of the germinal epithelium of testes and sperm production.
- LH works with FSH to stimulate estrogen secretion and rupture of mature follicles to release egg or ovum.

SCIED MDCAT

- It also causes the lutenization of mature follicles and acts synergistically with prolactin to maintain corpus luteum (and hence the progesterone it secretes).
- ICSH in the male stimulates the interstitial cells of the testes to secrete testosterone.



Median Lobe

- Median lobe secretes MSH.
- Its inhibition of secretion is controlled by hypothalamus.
- External light governs its secretion.
- More secretion in pregnancy stimulates melanocytes in skin to produce brown pigment, melanin, which darkens the skin.
- Excess MSH is secreted in Addison's disease. One of the symptoms of which is darkening of skin.

Posterior Lobe

1. Antidiuretic Hormone (ADH)/ Vasopressin

- Its secretion is caused by decrease in blood pressure, blood volume and osmotic pressure of the blood which is detected by osmoreceptors in hypothalamus.
- External sensory stimuli also influence hypothalamic neurosecretory cells.
- Increased levels cause increased water reabsorption in distal parts of nephron.
- A lack of this hormone produces ***diabetes insipidus***, characterized by production of large quantities of dilute urine and great thirst.

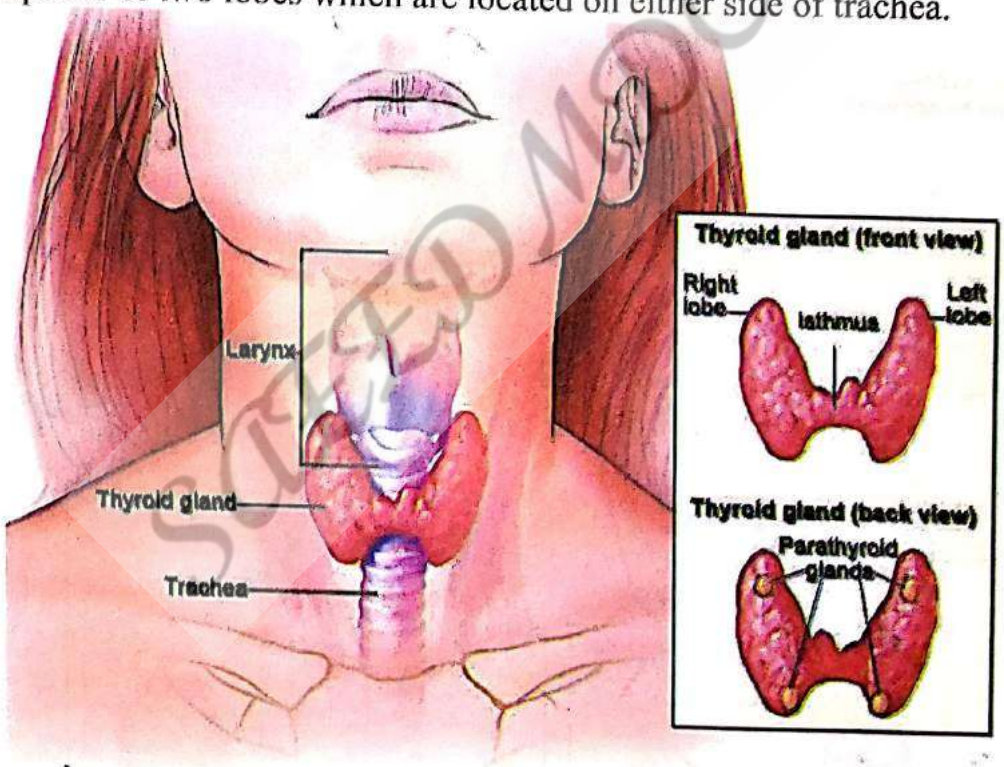
2. Oxytocin

- Its release is stimulated by distension of cervix, decrease in progesterone level in blood and neural stimuli during parturition and suckling.
- Primary action is on smooth muscles, particularly in the uterus during child birth and also causes milk ejection from mammary glands.

THYROID GLAND

Introduction

- Thyroid gland is located below the larynx (voice box).
- It is composed of two lobes which are located on either side of trachea.



Hormones

- Thyroxin (Tetra-iodothyronine/ T4)
- Tri-iodothyronine (T3)
- Calcitonin

Control

- T3 and T4
 Negative physiological control by anterior pituitary via TSH.
- Calcitonin
 Circulating calcium levels in blood

Functions

T3 and T4

- Rathyroxinal ...

- They act on basal metabolic rate by stimulating the breakdown of glucose and release of heat and generation of ATP.
- They also act in conjunction with somatotropin in bringing about growth.
- They act directly on brain cells causing them to differentiate.

Calcitonin

It regulates blood calcium level. High Ca^{+2} ion concentrations in the blood causes stimulation of the synthesis and release of calcitonin.

Abnormalities of T3 and T4

Overproduction

- Excess thyroxine produces a condition called ***Graves' disease*** which is characterized by ***exophthalmic goiter*** and increase in the basal metabolic rate.
- This can lead to cardiac failure if prolonged.
- It is caused by production of an abnormal body protein which continuously stimulates thyroid to excessive secretion.

Under-secretion

- If congenitally deficient, the lack of thyroxin causes ***cretinism***, where individuals fail to develop normally. They are small, have coarse scanty hair, thick yellowish skin and are mentally retarded. They also fail to develop sexually.
- Deficiency later in life, perhaps due to iodine deficiency, produces swelling of neck (goiter) and may lead to deposition of excess fat as a result of which weight is increased. This condition is known as ***myxedema***. It is characterized by puffiness of hand and skin. All body and mental processes are retarded.

Abnormalities of Calcitonin

- Excess or deficiency leads to disturbance of calcium metabolism with its associated effects on nerve, skeleton, muscle, blood etc.

PARATHYROID GLAND

Introduction

- In man, the glands are found embedded in the posterior part of the lateral lobes of the thyroid.
- These are four in number (2 pairs).

Hormone

- These produce a hormone called ***parathormone***.

Control

- Low levels of Ca^{+2} stimulate the parathyroid directly to increase the parathormone production.
- High levels of Ca^{+2} suppress its release.

Abnormalities

- Under-activity causes a drop in blood Ca^{+2} which in turn lead to ***muscular tetany***.
- Over-activity would lead to a ***progressive demineralization*** of the bones similar to ***rickets***, as well as to the formation of ***massive kidney stones***.

PANCREAS

Introduction

- Pancreas is a dual gland that acts ***both as exocrine*** and ***endocrine gland***.
- Endocrine portion of pancreas contains ***Islets of Langerhans***.

Hormones

- The Islets contain large number of ***β-cells*** associated with ***insulin production***.
- The smaller number of ***α-cells secretes glucagon***.

Control

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- This is under control of the pituitary trophic hormones, ***STH*** and ***ACTH*** and also responds directly to the ***level of blood glucose***.

Metabolic Functions of Insulin

- In general, insulin depresses blood glucose levels, in a variety of ways which include:

(i) Increasing glycogen synthesis
(ii) Increasing cell utilization of glucose
(iii) Stimulates conversion of glucose into proteins and lipids, which in turn reduce glucose levels
(iv) Inhibit the hydrolysis of glycogen in the liver and muscles

Metabolic Functions of Glucagon

- Glucagon is essentially ***antagonistic to insulin*** and causes an increase in blood glucose levels. It does this mainly by:

(i) Promoting breakdown of glycogen to glucose in the liver and muscles
(ii) Increasing the rate of breakdown of fats

Abnormalities of Insulin

Under-secretion

- Failure to produce insulin leads to a condition called ***diabetes mellitus***. The symptoms include:

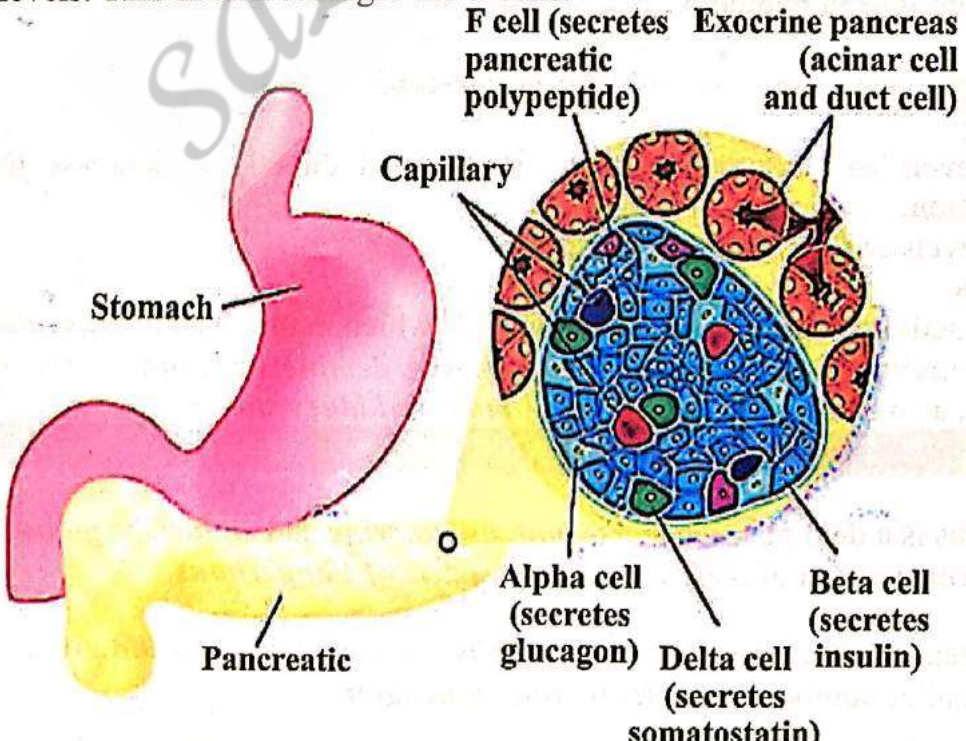
(i) High level of blood sugar (***Hyperglycemia***)
(ii) Sugar in the urine (***Glycosuria***)
(iii) A disturbance of the body's osmotic equilibrium
(iv) Derangement of the nervous system
(v) Toxic metabolites from fat (which need 'glucose energy' for their oxidation) also accumulate and are only lost from the kidney with valuable metal cations.
(vi) The body becomes dehydrated

Overproduction

- If excess insulin is produced, the utilization of sugar is too great and its level falls in the blood (hypoglycemia) which upsets nerve and muscle functioning.

Abnormalities of Glucagon

- Glucagon abnormalities seems to be rare endocrine disorders.
- Tumors on the β-cells will cause excess glucagon secretions and consequently high blood glucose levels. This in turn damages the α-cells.



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CRITICAL THINKING

10. Trace down the pathway of Glucagon from its source to its target site:

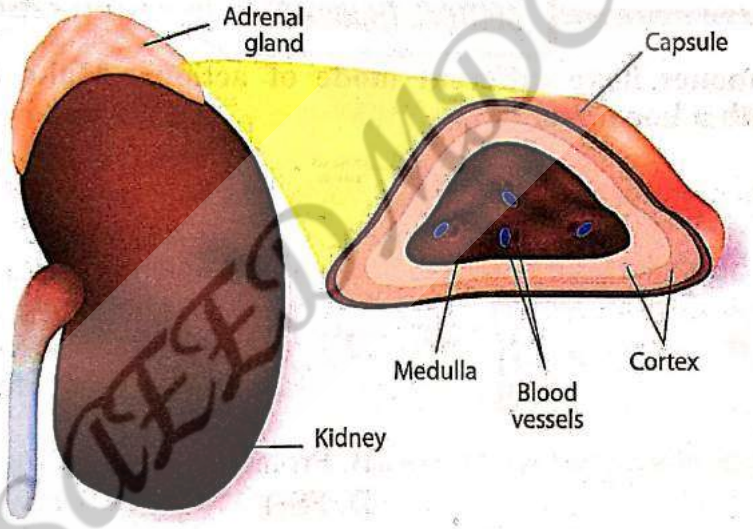
1. **Inferior vena cava**
2. **Heart, lungs, heart**
3. **Pancreatic vein**
4. **Aorta**
5. **Target site**

A. 1, 2, 3, 4, 5
B. 2, 1, 3, 4, 5
C. 3, 2, 1, 4, 5
D. 3, 1, 2, 4, 5

ADRENAL GLANDS

Introduction

- A pair of adrenal gland is present, one on top of each kidney.
- These are also called as glands of emergency or supra-renal glands.
- Each adrenal gland is composed of an inner portion called ***adrenal medulla*** and outer portion is called ***adrenal cortex***.



Adrenal Medulla

- Inner portion of adrenal gland is called adrenal medulla.

Hormones

- The medulla produces the hormones ***adrenaline/epinephrine*** and ***noradrenalin/nor-epinephrine***.

Control

- Both adrenalin and nor-adrenalin are secreted in stress situations.
- They are influenced by sympathetic nervous system.

Functions

- Essentially adrenaline dilates blood vessels in certain parts of the body such as the skeletal muscles and increases the heart's output.
- Noradrenaline constricts blood vessels but again only in certain areas such as the gut.
- Effects of the two hormones are synergistic in raising blood pressure.
- Adrenaline and noradrenaline promote the release of glucose from liver glycogen and reinforce the effects of the sympathetic system.

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Abnormalities

- Rarely found, but in excess, these hormones lead to abnormally high blood pressure.
- In rats whose adrenal medulla has been removed surgically, the ability to withstand any stress situation – such as cold – is markedly diminished.

Adrenal Cortex

- Outer portion of adrenal gland is called adrenal cortex.

Hormones

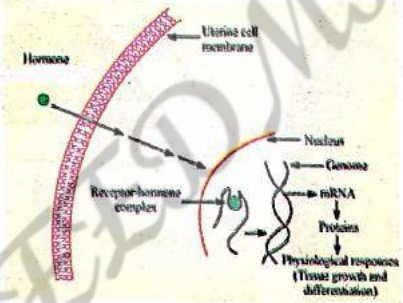
- The adrenal cortex secretes corticosteroids such as ***cortisol***, ***corticosterone***, ***aldosterone*** and ***androgenic hormones***.
- Cortisol is the glucocorticoid.
- Corticosterone is both a glucocorticoid and a mineralocorticoid.
- Aldosterone is the principal mineralo-corticoid.

Control

- Hormones of adrenal cortex are secreted under influence of ACTH from adrenal cortex.

CRITICAL THINKING

11. Different hormones have different mode of actions. Make a link of given mechanism with a hormone:



A. Cortisone
B. Prolactin
C. Glucagon
D. FSH

Functions

- The adrenal cortex is active at all times but especially so following shock or stress situation or infections.
- Cortisol brings about an increase in blood glucose level mainly by its production from protein and antagonizing the action of insulin.
- Corticosterone increases blood glucose levels and regulate mineral ion balance.
- Aldosterone conserves the level of Na^+ in the body by preventing their loss from the kidney tubules.

Abnormalities

Under-secretion of Corticosteroids

- The destruction of the adrenal cortex, such as occurs in ***Addison's disease***, will lead to general metabolic disturbance, in particular weakness of muscle action and loss of salts.

SALEEM MDCAT

- Stress situations, such as cold, which would normally be overcome, lead to collapse and death.

Overproduction of Corticosteroids

- The reverse of this is found in ***Cushing's disease*** where too much cortical hormone is produced. Symptoms are an excessive protein breakdown resulting muscular and bone weakness. The high blood sugar disturbs the metabolism as in diabetes.

Overproduction of Androgens

- Androgens cause development of the secondary male characteristics.
- Very small amounts of androgens are secreted in both male and female by adrenal glands.
- A tumor on the inner part of the adrenal cortex in a female can cause excess androgens to be produced and thus the development of certain male characteristics. Such cases are very rare.

GONADS

Ovaries

Hormones

Ovaries are involved in production and secretion of female sex hormones mainly estrogen and progesterone.

Estrogen

Production and Control

- Estrogens are secreted by ripening follicles whose development has been initiated by FSH from the pituitary.
- In many species produced by interstitial cells of the ovary.

Functions

- Bring about the development of the ***secondary sexual characters*** in the female.
- Cause thickening of uterine wall.
- At a point during the estrous or menstrual cycle, exert a positive feedback which results in a sharp rise in LH output by the pituitary.
- They also aid in healing and repair of uterine wall after menstruation.
- Under the influence of estrogen, some of the cells of uterine wall become glandular and start secreting proteinaceous secretions which are taken up by the embryo during its early stages of development.

Abnormalities

- Deficiency of the sex hormones, for one reason or another, leads in the young of failure to mature sexually and sterility in the adult.

Progesterone

Production and Control

- Produced by the ruptured follicle in response to LH from the pituitary

Functions

- It inhibits further FSH secretion from the pituitary, thus preventing any more follicles from ripening.
- It also affects uterus, causing further thickening and vascularization of its wall and other areas of the female body, preparing it for maintaining the state of pregnancy.
- It suppresses ovulation that is why it is a major constituent of birth control pill.

Testes

Hormones

- The testes consist of many coiled seminiferous tubules where the spermatozoa develop.
- Between the tubules, regions of interstitial cells produce gonadal hormones called testosterone and 17 β-hydroxytestosterone.
- After the initiation of development, the sex organs in the fetus produce them and their level rises fairly consistently until puberty.
- After puberty the supply of LH/ICSH, and therefore the level of testosterone, remains constant.

Functions

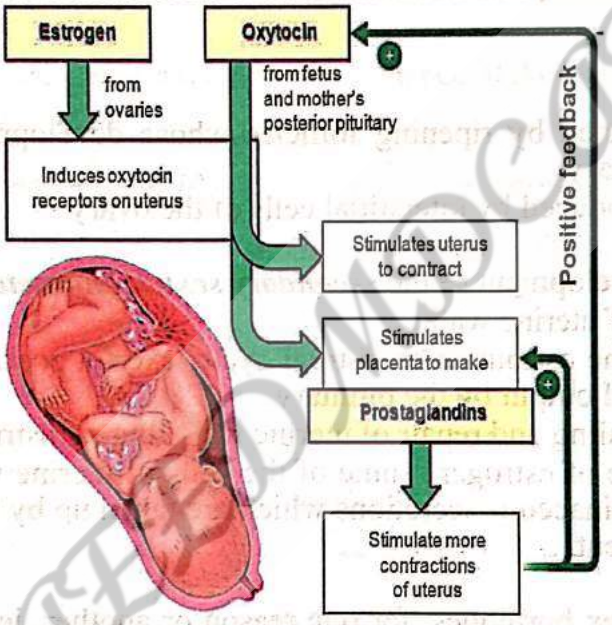
- In the fetus, it initiates the development of the sex organs.
- At puberty, it brings about development of the male secondary characteristics and promotes the sex drive.
- The castrated male fails to develop secondary sexual characteristics and his body tends more towards the form of the immature female.

HORMONAL FEEDBACK MECHANISM

- It is a type of interaction in which a controlling mechanism is itself controlled by the products of reactions it is controlling.
- After receiving the signal, a change occurs to correct the deviation by depressing it with negative feedback or enhancing it with positive feedback.

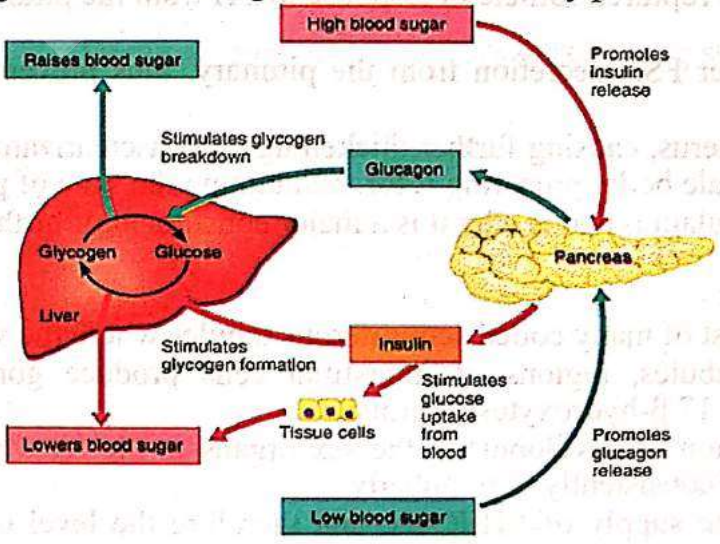
Positive Feedback Mechanism

- These responses are not homeostatic and are rare in healthy individuals.
- In positive feedback, an end product speeds up its production.
- An example of positive feedback is childbirth.



Negative Feedback Mechanism

- In this system, an endocrine gland is sensitive either to the concentration of a substance it regulates or to the concentration of a product from a process it controls.
- For example, regulation of blood glucose in the blood by pancreatic endocrine cells.



TOPIC-6 » DIVERSITY AMONG ANIMALS

COURSE CONTENT

- Introduction and characteristics of Animals
- Grade Radiata, Grade Bilateria
- Diploblastic and Triploblastic organization
- Classification according to Coelom (body cavity)
- Protostomes, Deuterostomes
- Invertebrate and Vertebrate Phyla

INTRODUCTION, GRADE RADIATA, BILATERIA

Kingdom Animalia

- The name Animalia is derived from Latin word anima meaning breath or soul.
- All the animals are multicellular heterotroph and usually acquire food by ingestion followed by digestion.

Complexity in Kingdom Animalia

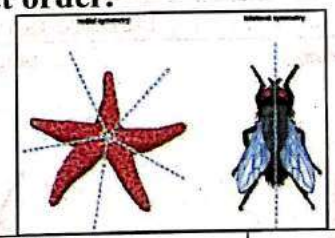
- Simplest of the animals belong to subkingdom ***Parazoa***. These animals lack tissues organized into organs and have indeterminate shape and are asymmetrical. Phylum porifera is included in parazoa.
- They have cellular grade of organization.
- The subkingdom **Eumatozoa** includes animals of other phyla which have symmetry and organization.
- In eumatozoa, similar cells are grouped together into a highly coordinated unit called tissue. The tissues are assembled into larger functional units called organs. Different organs operate together as organ system.

CRITICAL CONCEPT!

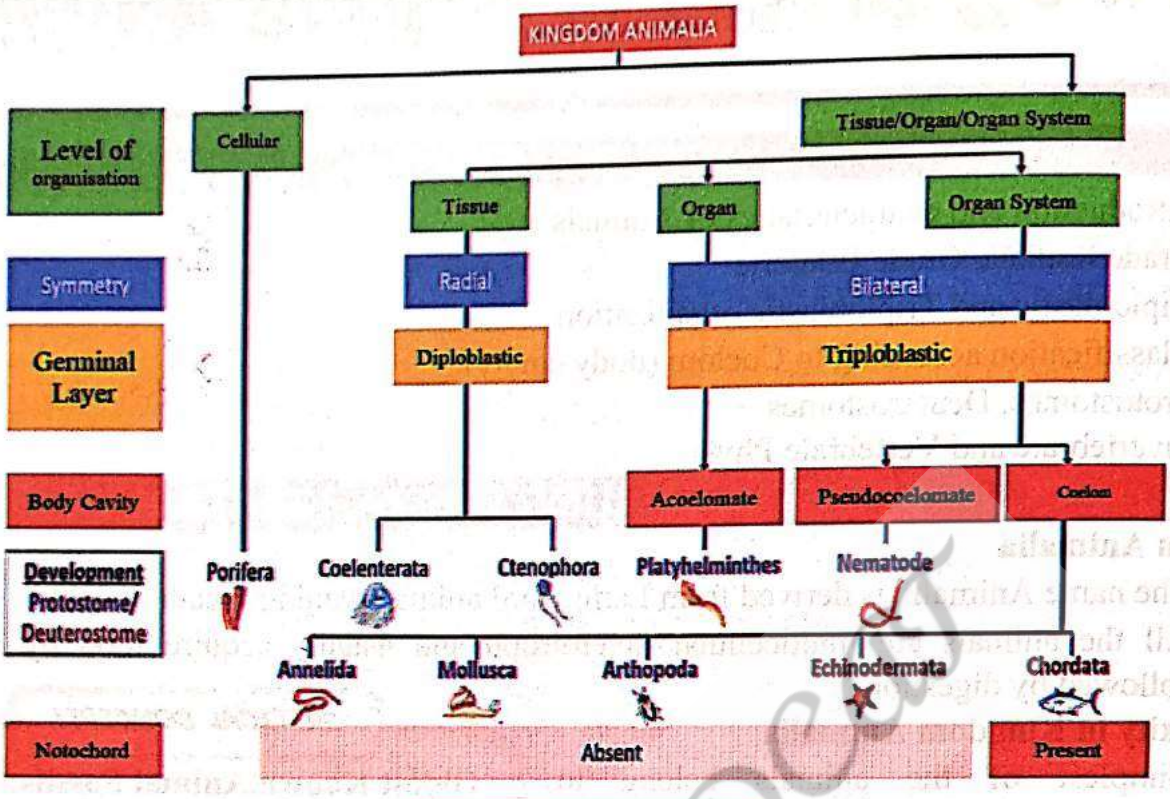
Oldest Known Animal Fossils:
As one would expect based on their phylogenetic position, fossil sponges are among the oldest known animal fossils.

CRITICAL THINKING?

1. Two types of symmetries are present in kingdom animalia. Relate feature of these symmetries in correct order.



	Grade Radiata	Grade Bilateria
A.	No right- and left-hand sides	No anterior and posterior ends
B.	Anterior and posterior ends	Defined dorsal and ventral surfaces
C.	Defined dorsal and ventral surfaces	Right and left hand sides
D.	No dorsal and ventral surfaces	Triploblastic organization



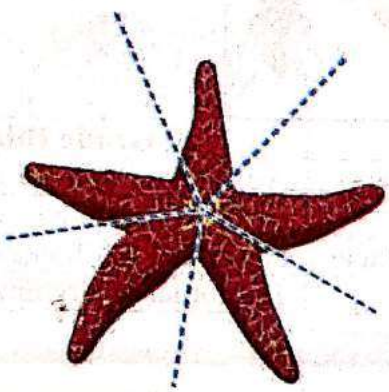
CRITICAL THINKING

2. **According to the evidence collected so far, the animal kingdom is:**
 A. Monophyletic B. Paraphyletic
 C. Polyphyletic D. Euphyletic

Classification on Base of Symmetry

GRADE RADIATA	GRADE BILATERIA
A condition or organization in which the parts of the body are arranged around a central axis in such a way that ***any plane*** passing through the central axis divides the animal in ***halves*** that are ***mirror images***	A condition or organization in which the parts of the body are arranged around a central axis in such a way that an imaginary line divides organism into ***two equal parts*** in ***one plane***
No anterior and posterior ends	Anterior and posterior ends
No right and left hand sides	Right and left hand sides
No dorsal and ventral surfaces	Defined dorsal and ventral surfaces

radial symmetry



bilateral symmetry



DIPLOBLASTIC AND TRIPLOBLASTIC ORGANIZATION		
FEATURES	DIPLOBLASTIC	TRIPLOBLASTIC
Grade	Radiata	Bilateria
Symmetry	Radial	Bilateral
Germinal layers	2: Ectoderm and Endoderm	3 layers: Ectoderm, Mesoderm and Endoderm
Complexity	Less	High
Mesoglea/ Mesenchyme	Present	Absent
Phylum	Cnidaria	Platyhelminthes to Chordates

CRITICAL THINKING

3. Polymorphism and radial symmetry in an adult phase of an organism having triploblastic organization can be related respectively with:

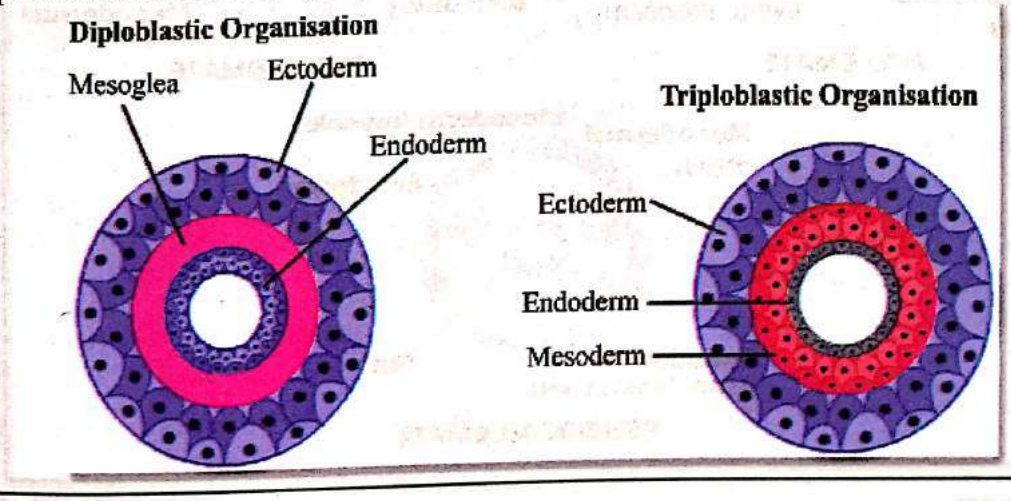
A. Cnidaria, Echinodermata
B. Echinodermata, Coelenterata
C. Porifera, Cnidaria
D. Arthropoda, Echinodermata

Diploblastic Organization

- There is no special transport system in these animals. Most substances are distributed within their body the by process of diffusion.
- There is no central nervous system in these animals. A neuron net is present.
- There is only one cavity in the body called ***gastrovascular cavity*** or ***coelenterons*** which has only mouth which serves for the entry of food and water and also for the removal of wastes along with water. This is known as ***sac like digestive system***.
- They reproduce both asexually and sexually.
- Diploblastic animals are placed in phylum ***Cnidaria***.

Triploblastic Organization

- After embryonic development these layers in most triploblastic animals are not distinct as separate layers of cells but are represented by the structures formed from them.
- The cells of these animals show greater degree of specialization. These have specialized organs and organ systems.
- The systems such as integumentary and nervous system develop from ectoderm.
- Mesoderm gives rise to muscular, skeletal and reproductive systems.
- Endoderm forms the lining of digestive tract and glands of digestive system such as liver.
- Triploblastic animals may be acoelomate, pseudocoelomate or coelomate.



CLASSIFICATION ACCORDING TO COELOM (BODY CAVITY)

Acoelomates

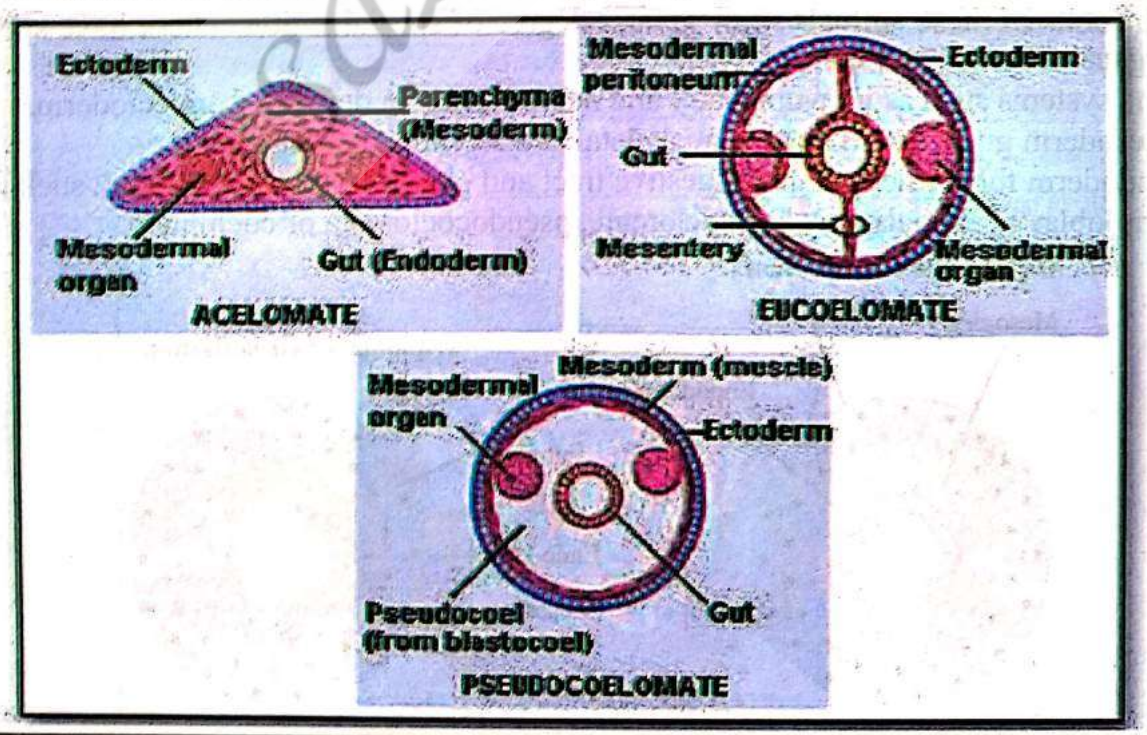
- This group includes phylum ***platyhelminthes.***
- There is ***no body cavity or coelom.***
- Mesoderm forms a loose, cellular tissue ***mesenchyma*** or ***parenchyma*** which fills the space between the ectoderm and endoderm. It forms a packing around the internal organs of the animals to support and protect them.
- The gut is ***sac-type*** and there is no special transport system.
- Only excretory system is developed for the transport of excretory products. This system consists of ***flame cells***, excretory ducts and excretory pores.
- Nervous system is well developed.

Pseudocoelomates

- This group includes phylum ***Aschelminthes.***
- The space between the body wall and the digestive tube is called ***pseudocoelom*** (false body cavity).
- Pseudocoelom is not homologous to true coelom because it is not lined by coelomic epithelium.
- It has no relation with the reproductive and excretory organs.
- It develops from the blastocoel of the embryo and is bound externally by the muscles and internally by the cuticle of intestine.

Coelomates

- ***Coelom*** is cavity present between the body wall and the alimentary canal and is lined by mesoderm.
- The mesoderm splits into outer parietal layer which underlines the body wall and the visceral layer which covers the alimentary canal and the cavity between them is the true coelom. It is filled with fluid called ***coelomic fluid.***
- This group includes animals from ***annelids to chordates.***
- In coelomates, gut includes more complexity and neuro-sensory system is well developed along with excretory system, circulatory system, respiratory and reproductive system.
- Coelomates are further divided into two groups proterostomia and deuterostomes.



CRITICAL THINKING?

4. **Nematode is the 1st phylum which evolved tube like digestive system. Epithelial lining of gastrointestinal tract is formed from:**
 A. Mesoderm B. Ectoderm
 C. Endoderm D. Hypoderm
5. **Among the characteristics, which one is unique to animals:**
 A. Gastrulation B. Multicellularity
 C. Sexual reproduction D. Flagellated sperm
6. **What is the correct sequence of the following four events during an animal's development?**
 1. Gastrulation 2. Metamorphosis 3. Fertilization 4. Cleavage
 A. 4 → 3 → 2 → 1 B. 4 → 3 → 1 → 2
 C. 3 → 2 → 4 → 1 D. 3 → 4 → 1 → 2

PROTOSTOMES AND DEUTEROSTOMES

Series Proterostomia	Series Deuterostomia
Cleavage is spiral and indeterminate.	Cleavage is radial and indeterminate.
Blastopore gives rise to mouth.	Blastopore forms anus.
Coelom is formed by splitting of mesoderm (Schizocoelous).	Coelom is developed from archenteron (Enterocoelous).
Mesoderm is derived from cells on anterior lip of blastopore.	Mesoderm is derived from wall of developing gut (archenteron).
It includes phylum annelida, Mollusca and arthropoda.	It includes phylum Echinodermata, hemichordate and chordata.

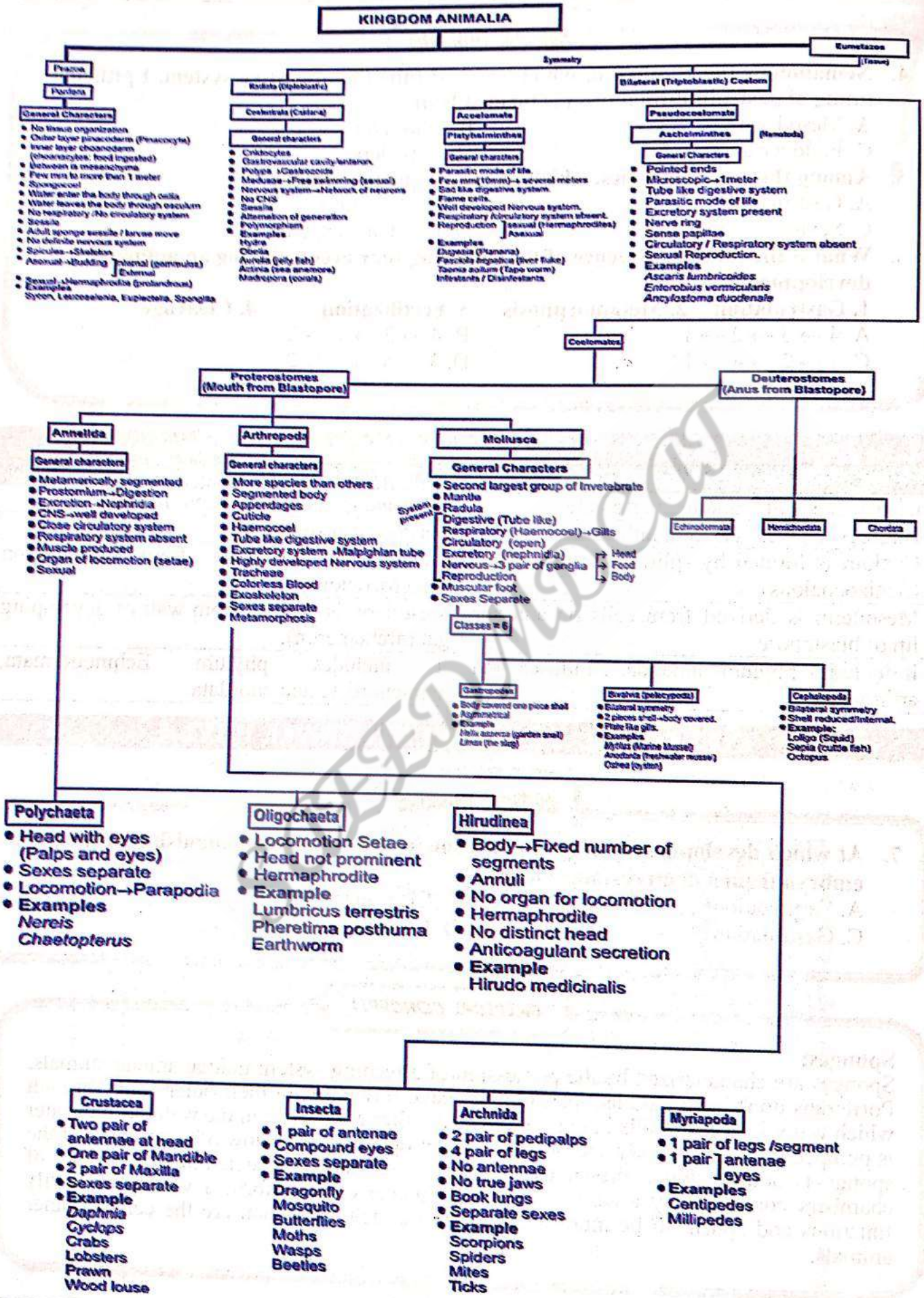
INVERTEBRATE AND VERTEBRATE PHYLA

CRITICAL THINKING?

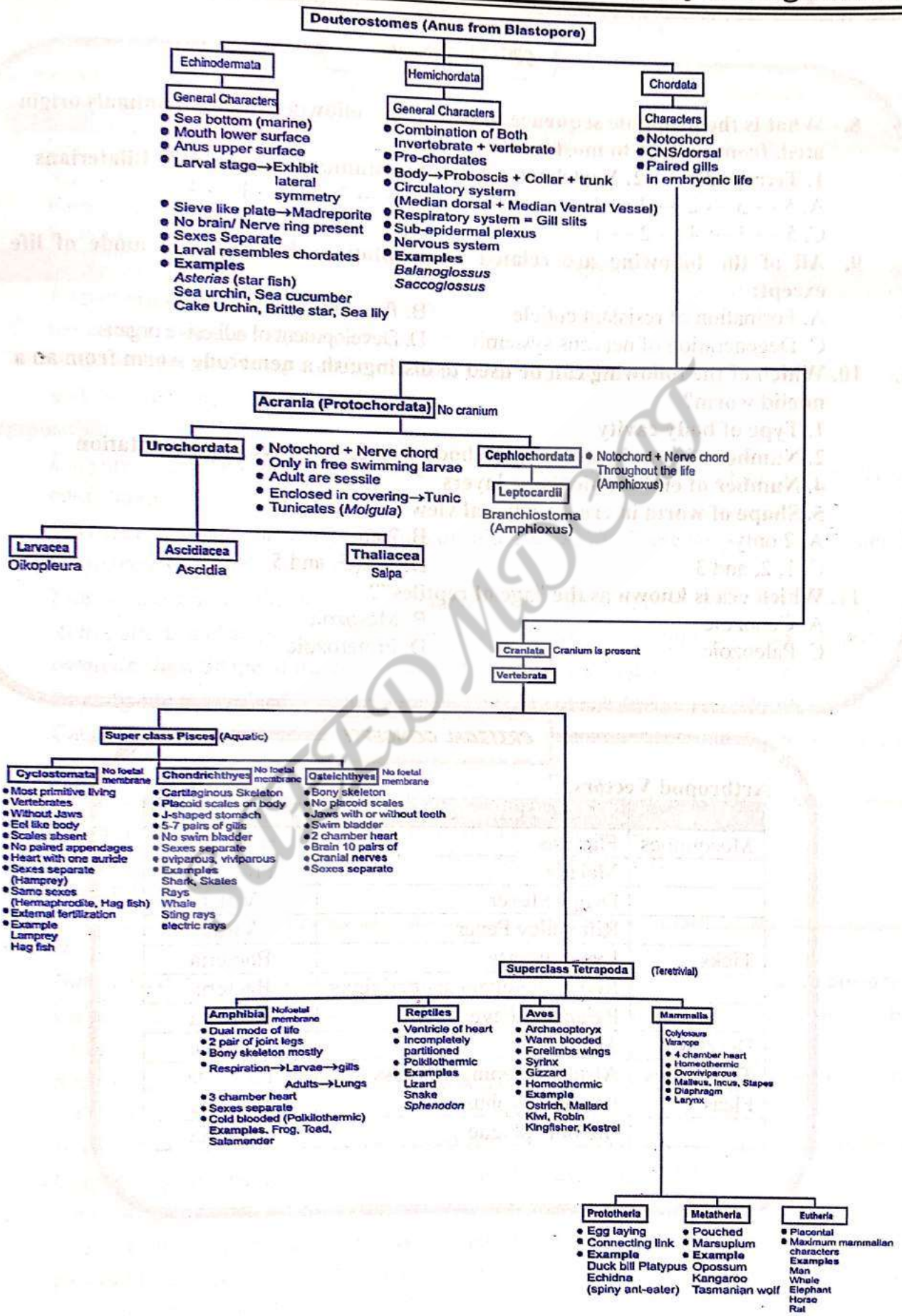
7. **At which developmental stage should one be able to first distinguish a protostome embryo from a deuterostome embryo?**
 A. Fertilization B. Cleavage
 C. Gastrulation D. Coelom formation

CRITICAL CONCEPT!

Sponges:
Sponges are characterized by the possession of a feeding system unique among animals. Poriferans don't have mouths; instead, they have tiny pores in their outer walls through which water is drawn. Cells in the sponge walls filter goodies from the water as the water is pumped through the body and out other larger openings. The flow of water through the sponge is unidirectional, driven by the beating of flagella which line the surface of chambers connected by a series of canals. Sponge cells perform a variety of bodily functions and appear to be more independent of each other than are the cells of other animals.



PREP Mission


Deuterostomes (Anus from Blastopore)
Echinodermata
General Characters
Sea bottom (marine)
Mouth lower surface
Anus upper surface
Larval stage→Exhibit lateral symmetry
Sieve like plate→Madreporite
No brain/ Nerve ring present
Sexes Separate
Larval resembles chordates
Examples
Asterias (star fish)
Sea urchin, Sea cucumber
Cake Urchin, Brittle star, Sea lily
Hemichordata
General Characters
Combination of Both Invertebrate + vertebrate
Pre-chordates
Body→Proboscis + Collar + trunk
Circulatory system (Median dorsal + Median Ventral Vessel)
Respiratory system = Gill slits
Sub-epidermal plexus
Nervous system
Examples
Balanoglossus
Saccoglossus
Chordata
Characters
Notochord
CNS/dorsal
Paired gills in embryonic life
Acrania (Protochordata) No cranium
Urochordata
Notochord + Nerve chord
Only in free swimming larvae
Adult are sessile
Enclosed in covering→Tunic
Tunicates (Molgula)
Cephlochordata
Notochord + Nerve chord Throughout the life (Amphioxus)
Leptocardii
Branchiostoma (Amphioxus)
Larvacea
Oikopleura
Ascidiacea
Ascidia
Thaliacea
Salpa
Craniata Cranium is present
Vertebrata
Super class Pisces (Aquatic)
Cyclostomata No foetal membrane
Most primitive living
Vertebrates
Without Jaws
Eel like body
Scales absent
No paired appendages
Heart with one auricle
Sexes separate (Hamprey)
Same sexes (Hermaphrodite, Hag fish)
External fertilization
Example
Lamprey
Hag fish
Chondrichthyes No foetal membrane
Cartilaginous Skeleton
Placoid scales on body
J-shaped stomach
5-7 pairs of gills
No swim bladder
Sexes separate
oviparous, viviparous
Examples
Shark, Skates
Rays
Whale
Sting rays
electric rays
Osteichthyes No foetal membrane
Bony skeleton
No placoid scales
Jaws with or without teeth
Swim bladder
2 chamber heart
Brain 10 pairs of Cranial nerves
Sexes separate
Superclass Tetrapoda (Teretrivial)
Amphibia Nofoetal membrane
Dual mode of life
2 pair of joint legs
Bony skeleton mostly
Respiration→Larvae→gills
Adults→Lungs
3 chamber heart
Sexes separate
Cold blooded (Poikilothermic)
Examples. Frog, Toad, Salamender
Reptiles
Ventricle of heart
Incompletely partitioned
Poikilothermic
Examples
Lizard
Snake
Sphenodon
Aves
Archaeopteryx
Warm blooded
Forelimbs wings
Syrinx
Gizzard
Homeothermic
Example
Ostrich, Mallard
Kiwi, Robin
Kingfisher, Kestrel
Mammalia
Colyosaura
Varanope
4 chamber heart
Homeothermic
Oviviviparous
Malleus, Incus, Stapes
Diaphragm
Larynx
Prototheria
Egg laying
Connecting link
Example
Duck bill Platypus
Echidna
(spiny ant-eater)
Metatheria
Pouched
Marsupium
Example
Opossum
Kangaroo
Tasmanian wolf
Eutheria
Placental
Maximum mammalian characters
Examples
Man
Whale
Elephant
Horse
Rat

SOLVED MCQ

CRITICAL THINKING

8. **What is the probable sequence in which the following clades of animals originated, from earliest to most recent?**
 1. Tetrapods 2. Vertebrates 3. Deuterostomes 4. Amniotes 5. Bilaterians
 A. 5 → 3 → 2 → 4 → 1 B. 5 → 3 → 2 → 1 → 4
 C. 5 → 3 → 4 → 2 → 1 D. 3 → 5 → 4 → 2 → 1
9. **All of the following are related to adaptations for parasitic mode of life except:**
 A. Formation of resistant cuticle B. Presence of a specific host
 C. Degeneration of nervous system D. Development of adhesive organs
10. **Which of the following can be used to distinguish a nematode worm from an annelid worm?**
 1. Type of body cavity
 2. Number of muscle layers in the body wall 3. Presence of segmentation
 4. Number of embryonic tissue layers
 5. Shape of worm in cross-sectional view
 A. 2 only B. 2 and 3
 C. 1, 2, and 3 D. 1, 2, 3, and 5
11. **Which era is known as the "age of reptiles"?**
 A. Cenozoic B. Mesozoic
 C. Paleozoic D. Proterozoic

CRITICAL CONCEPT!

Arthropod Vectors:

Vector	Disease	Pathogen type
Mosquitoes	Flariasis	Helminth
	Malaria	Protozoa
	Dengue fever	Virus
	Rift valley Fever	Virus
Ticks	Lyme disease	Bacteria
	Rocky mountain spotted fever	Bacteria
	Relapsing Fever	Bacteria
Deerflies	Tularemia	Bacteria
Tsetse flies	African sleeping sickness	Protozoa
Fleas	Endemic typhus	Bacteria
	Bubonic plague	Bacteria

TOPIC-7 ENZYMES

COURSE CONTENT

- Introduction and Characteristics of Enzymes
- Mechanism of Enzyme Action
- Factors Affecting the Rate of Enzyme Action
- Enzyme Inhibition

INTRODUCTION OF ENZYMES

Enzymes are biological molecules (proteins) which catalyze a biochemical reaction and remain unchanged after completion of reaction.

Without enzymes, reactions are possible but they would proceed at very low speed making life impossible.

Composition

- Enzymes are ***globular proteins*** made of one or more polypeptide chains having tertiary conformation.
- This protein part is made up of ***hundreds of amino acids***. These enzymes have tertiary or quaternary structure.
- Most of the amino acids maintain its globular shape while few are involved in catalysis.
- ***Active site*** is a charge bearing cavity of enzyme having two regions i.e. ***binding site and catalytic sites.*** Shape of the active site is designed according to the substrate.
- Binding site is involved in recognition and binding of substrate with enzyme.
- Catalytic site is involved in transformation of enzyme-substrate complex into enzyme and product.

CRITICAL THINKING

1. Which of the following enzymes is attached to an organelle in a cell?

A. NADP reductase
B. RNA Polymerase II
C. Phosphofructokinase
D. Citrate synthase

Cofactor

- ***Non-protein part*** of enzyme that is required for its proper functioning is called ***co-factor***.
- Cofactor acts as bridge between enzyme and substrate. It also acts as source of chemical energy for catalysis.
- Such an inorganic cofactor that is detachable is called activator e.g. metal ions like Fe^{+2}, Mg^{+2}, Cu^{+2}, Zn^{+2} etc.
- If a cofactor is organic and loosely attached to the protein part, it is known as ***coenzyme***. Coenzymes are the derivatives of vitamins. For example, ATP, NAD^{+} and FAD^{+} are common coenzymes.
- If a cofactor or non-protein part is covalently bound to the protein part, it is called a ***prosthetic group***. It is permanently attached to enzyme. For example, cytochrome is prosthetic group of cytochrome oxidase.

- An activated enzyme consisting of polypeptide chain and a cofactor is known as ***holoenzyme***.
- An enzyme with its coenzyme or prosthetic group has been removed is called ***apoenzyme***.

CRITICAL CONCEPT!

Vitamins are Raw Material for Co-enzymes.

Vitamin	Coenzyme	Coenzyme Function
Vitamin B_2 (riboflavin)	Flavin mononucleotide or flavin adenine dinucleotide	Oxidation-reduction reactions involving two hydrogen atoms
Vitamin B_3 (niacin)	Nicotinamide adenine dinucleotide or nicotinamide adenine dinucleotide phosphate	Oxidation-reduction reactions involving the hydride ion (H^-)
Vitamin B_{12} (cyanocobalamin)	Methylcobalamin or deoxyadenoxylcobalamin	Intramolecular rearrangement reactions
Biotin	Biotin	Carboxylation reactions

CRITICAL THINKING?

2. Vitamin is a precursor for:

A. Haem B. ATP
C. FAD D. Mg^{2+}

CHARACTERISTICS OF ENZYMES

- Enzymes are biological molecules which catalyze a biochemical reaction and remain unchanged after completion of reaction.
- All enzymes are globular proteins, having specific chemical composition due to their component amino acids and specific shape.
- Even small amount of them can tremendously increase the efficacy of a biochemical reaction.
- They are specific for each type of a reaction or group of related reactions.
- Their presence ***does not affect the nature or properties*** of end products.
- They ***lower the activation energy*** of the reactants.
- They are sensitive to even a minor change in pH, temperature and substrate concentration.
- They ***require aqueous media*** for their activity.
- Some may require co- factor for their proper functioning.
- Some enzymes are potentially damaging, if they are manufactured in their active form.

CRITICAL CONCEPT!

Turnover Number:
The turnover number of an enzyme is the maximal number of molecules of substrate converted to product per active site per unit time.

CRITICAL THINKING

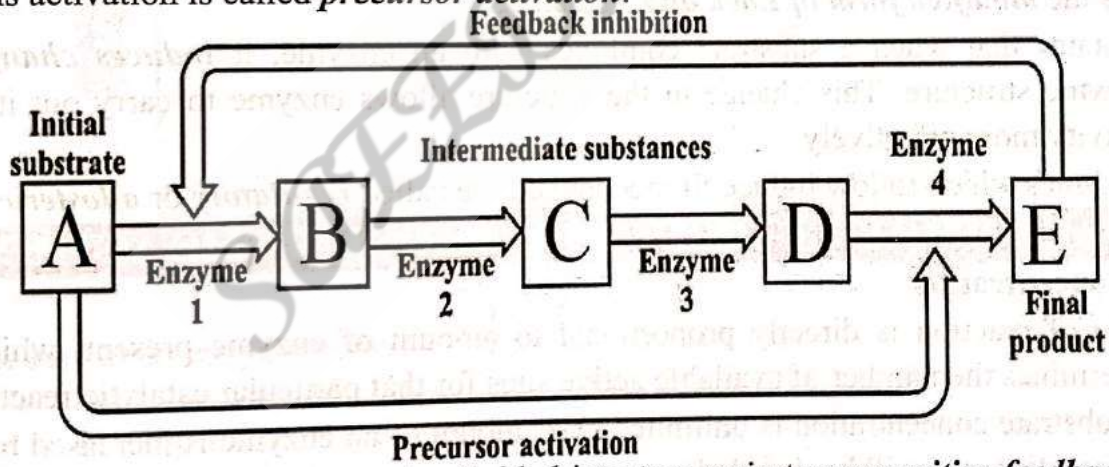
3. **An enzyme that is produced in its active form:**
A. EcoR1 B. Pepsin
C. Trypsin D. Chymotrypsin

MECHANISM OF ENZYME ACTION (MODELS)

Mechanism

E+S → ES Complex → EP Complex → E+P

- The active site of an enzyme is a ***three-dimensional cavity bearing a specific charge*** by which the enzyme reacts with its substrate.
- The active site is made of two definite regions i.e. binding site & a catalytic site.
- Binding site helps the enzyme in the recognition and binding of the proper substrate to produce an ***ES complex***.
- Activated catalytic site catalyzes the transformation of the substrate into product/s.
- Formation of ES complex activates the catalytic site.
- Activity of enzymes in a cell can be regulated by its products. When the activity of an enzyme is inhibited by its own product, it is called ***feedback inhibition*** or end product inhibition.
- Similarly, increase in concentration of substrate can cause increase in rate of reaction. This activation is called ***precursor activation***.



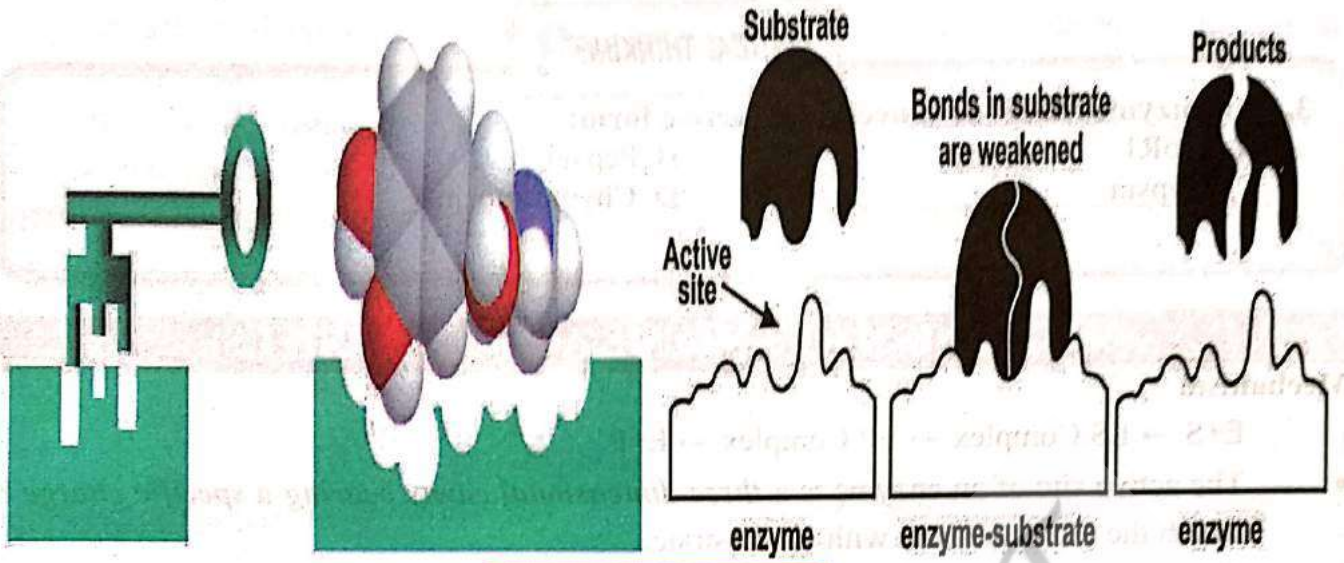
Typically, ***feedback*** loop can be divided into two main types: ***positive feedback*** loops, in which a change in a given direction causes additional change in the same direction, and ***negative feedback*** loops, in which a change in a given direction causes change in the opposite direction.

Models

Lock and Key Model

- ***Emil Fischer*** (1890) proposed Lock and Key model.
- As one specific key can open a specific lock, in the same manner a specific enzyme can transform a specific substrate into product/s.
- According to this model, active site is a ***rigid structure*** and thus there is ***no modification or flexibility*** in the active site before, during or after the enzyme action.
- It was proved later on that all the chemical reactions cannot be explained on the basis of

SOLEDAD Medical



CRITICAL THINKING

4. **Pick an enzyme that catalyzes two different substrates together but produces a single type of product:**
 A. Carbonic anhydrase B. DNase
 C. Pepsin D. Reverse transcriptase

Induce Fit Model

- D. Koshland (1959) proposed Induce Fit Model.
- It is the ***modified form of Lock and Key model.***
- It states that when a substrate combines with an enzyme, it ***induces changes*** in the enzyme structure. This change in the structure allows enzyme to carry out its catalytic activity more effectively.
- Enzymes which follow induce fit mechanism are called ***regulatory*** or ***allosteric enzymes.***

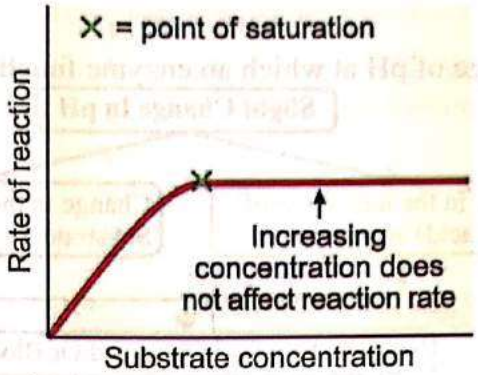
FACTORS AFFECTING THE RATE OF ENZYME ACTION

Enzyme Concentration

- Rate of reaction is directly proportional to amount of enzyme present, which in turn determines the number of available active sites for that particular catalytic reaction.
- If substrate concentration is unlimited and amount of an enzyme is increased by two-fold the reaction rate will be doubled.
- However, after a certain limiting concentration, the rate of the reaction will no longer depend upon this increase.

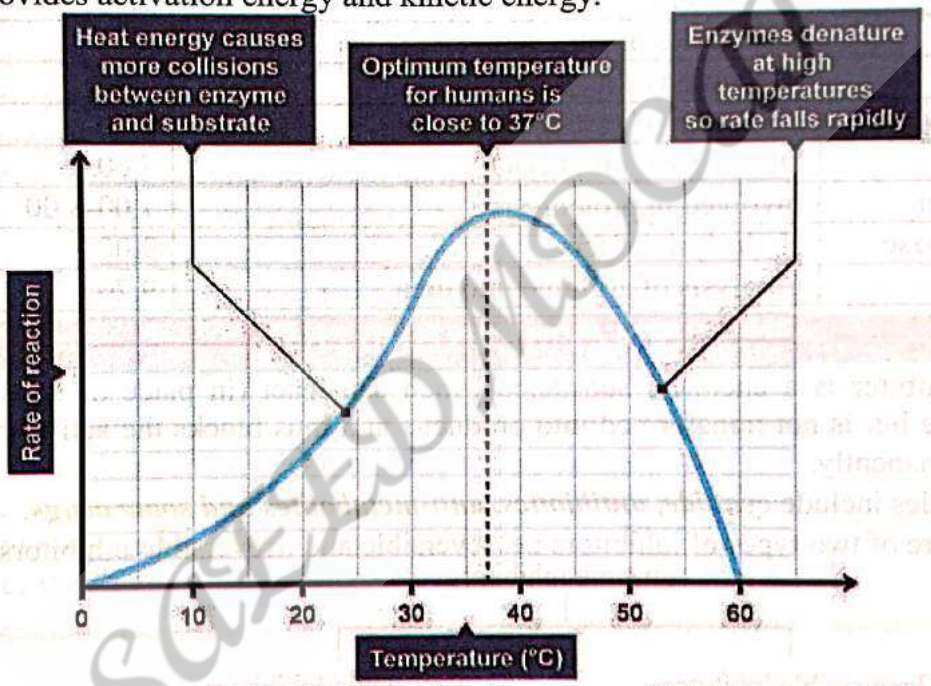
Substrate Concentration

- The rate of an enzyme controlled reaction is directly proportional to the substrate concentration provided that active sites on the enzyme are available.
- At higher concentration of enzyme, increase in substrate concentration increases reaction velocity. Reaction reaches to maximum at equilibrium state.
- When all active sites are occupied by substrate and no more available, this state is called state of saturation.



Temperature

- Heating increases molecular motions. Thus, the molecules of substrate and enzyme move more quickly, so probability of reactions to occur is increased.
- Heat provides activation energy and kinetic energy.



- The rate of an enzyme controlled reaction increases with an increase in temperature upto certain limits. Increase of 10°C in temperature doubles the rate of reaction.
- Optimum temperature is the temperature at which an enzyme works at its maximum rate e.g., for enzymes of our body 37°C is the optimum temperature.
- Increase in temperature above optimum value increases the vibrations of atoms in enzyme. If vibrations become too violent, globular structure essential for enzyme activity is lost and the enzyme is said to be denatured.
- If temperature is reduced to near or below freezing point, enzymes are inactivated.

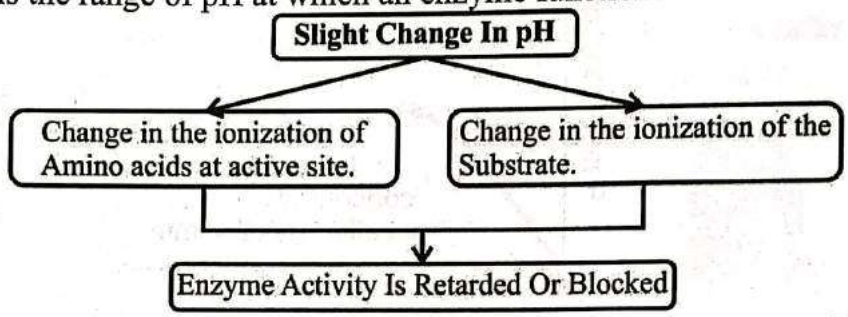
CRITICAL THINKING

5. Increased temperature above optimum usually do not effect_____ of enzymes.

A. Primary structure
B. Secondary structure
C. Tertiary structure
D. Quaternary structure

pH Value

- Optimum pH is the range of pH at which an enzyme functions most effectively.

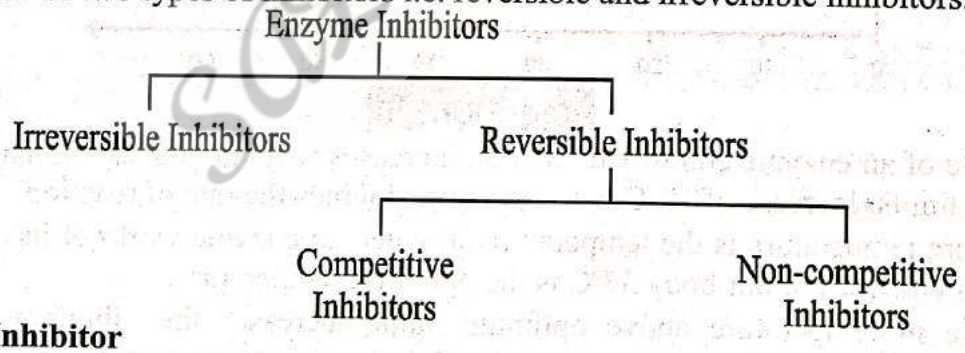


- Extreme changes in pH cause the bonds in the enzyme to break, resulting in the enzyme denaturation.

Enzyme	Function	Optimum pH Value
Pepsin	Digestion of proteins	2.00
Sucrase	Hydrolysis of sucrose	4.50
Enterokinase	Activation of trypsinogen	5.50
Salivary Amylase	Digestion of carbohydrate	6.80
Catalase	Decomposition of H_2O_2	7.60
Chymotrypsin	Involved in proteolysis	7.00-8.00
Pancreatic lipase	Hydrolysis of fats	9.00
Arginase	Catalysis of arginine into urea	9.70

ENZYME INHIBITION

- An inhibitor is a chemical substance which can react (in place of substrate) with the enzyme but is not transformed into product/s and thus blocks the active site temporarily or permanently.
- Examples include ***cyanide, antibiotics, anti-metabolites and some drugs***.
- They are of two types of inhibitors i.e. reversible and irreversible inhibitors.



Irreversible Inhibitor

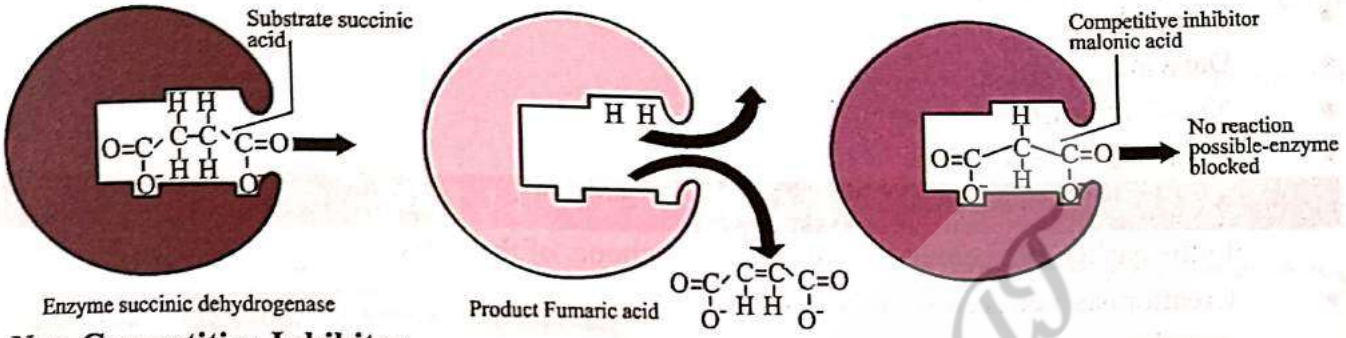
- They occupy the active sites by forming covalent bonds or they may physically block the active sites and they check the reaction rate by occupying the active sites.
- They destroy enzyme by altering the shape so that the substrate cannot bond to the active site.
- Examples of irreversible non-competitive inhibitors are ***cyanides and ions of heavy metals.***

Reversible Inhibitors

- They form weak linkages with the enzyme.
- Their effect can be neutralized, completely or partly by increase in the concentration of substrate.
- There are two types of reversible inhibitors i.e. competitive and non-competitive.

Competitive Inhibitors

- Competitive inhibitors are structurally similar to the substrate, hence can bind to the active site but can't activate the catalytic site, thus no products are formed.
- Competitive inhibition is usually temporary.
- Level of inhibition depends upon relative concentrations of substrate and inhibitor.
- This type of inhibition can be reversed by increasing concentration of substrate.



Non-Competitive Inhibitor

- Non- competitive inhibitors bind with the enzyme at the site other than active site. The other binding site of enzyme is called allosteric site.
- Structure of enzyme is altered so that even if a genuine substrate binds the active site, catalysis fails to take place.
- Feedback inhibition is an example of reversible non-competitive inhibition.

CRITICAL THINKING

6. All of the followings are cases of negative feedback inhibition except:
A. Effect of high amount of ATP on Phosphofructokinase
B. Effect of high amount of NADH on Pyruvate decarboxylase
C. Effect of increased amount of thyroxine in blood on TSH release
D. Effect of suckling on release on oxytocin

SOLUTIONS

TOPIC- 8 EVOLUTION

COURSE CONTENT

- Concept of Evolution
- Evolution of Eukaryotes from Prokaryotes
- Lamarckism
- Darwinism
- Neo-Darwinism
- Evidences of Evolution

CONCEPT OF EVOLUTION

In the earlier 19th century, there were two schools of thoughts.

- Creationists believed on theory of ***special creation***.
- Evolutionists believed on theory of ***natural selection***.

CRITICAL CONCEPT!

Interesting Fact:
No two animals are the same, even if they belong to the same species.

(i) Theory of Special Creation

According to this theory, all living things came into existence in their present forms especially and specifically created by nature. Among the scientists who believed in divine creation was C. Linnaeus. C. Linnaeus in the eighteenth-century classified organisms. He grouped similar species in the same genus and similar genera in one family. But as a natural theologian, he believed that species were permanent creations. C. Linnaeus was one of the believers of this theory.

(ii) Theory of Natural Selection

According to this theory, organisms evolved through time, with one type of organism giving rise to another type of organism.

It is ancient one starting from days of Aristotle to Darwin.

However, the present-day concept of evolution is based on history.

Scientist's Name	Life Span	Achievements
Linnaeus	1707-1778	Order in diversity of life, binomial nomenclature
Lamarck	1744-1829	Theory of evolution
Malthus	1766-1834	Essay on 'Principle of Population'.
Cuvier	1769-1832	Science of Palaeontology, earth's history by catastrophism.
Lyell	1797-1875	Principles of Geology
Darwin	1809-1882	1. Voyage of Beagle. 2. Books on origin of species. 3. Essay on origin of species.
Mendel	1822-1884	Papers on inheritance
Wallace	1823-1913	Sent his theory to Darwin
Hutton	1726-1797	Theory of Uniformitarianism

EVOLUTION OF EUKARYOTES FROM PROKARYOTES

Different speculations about the origin of first life form and evolution of prokaryotes into eukaryotes are mentioned briefly.

Hydrothermal Vent Hypothesis

Origin of First Life Form

- According to one concept, life may have originated in the oceans, in underwater hot springs called ***hydrothermal vents***. These vents could have supplied the energy and raw materials for the origin and survival of early life forms.
- Archaebacteria are considered as first life form, which support this vent hypothesis because they can tolerate ***temperature up to 120°C*** and undergone less evolutionary changes than any other living species.
- As bacteria are prokaryotes, so prokaryotes are considered as first life form on earth.

CRITICAL THINKING

1. Simplest organism would be:

A. *Nostoc* B. *Escherichia*
C. *Bacillus* D. *Thermus*

Evolution of Photosynthetic Organisms

- Nutrients produced in primitive environment would have limited early life. Photosynthesis, another source of nutrients, probably freed living organisms from a dwindling supply of nutrients.
- First photosynthetic organisms probably used ***hydrogen sulfide*** as a source of hydrogen for reducing carbon dioxide to sugars.
- Later water served this same purpose and oxygen liberated by photosynthetic reaction begun to accumulate in the atmosphere.

Evolution of Aerobic Respiration

- Accumulation of oxygen in atmosphere changed the primitive environment.
- Ozone developed by oxygen in upper atmosphere began to filter ultraviolet radiations from the sun. It is considered that about ***4.2 billion*** (420 million) years ago, enough protective ozone had built up to make life on land possible.
- Reducing atmosphere slowly changed into oxidizing atmosphere.
- Some living organisms began to utilize oxygen.
- Ironically, the change from a reducing atmosphere to an oxidizing atmosphere also means that life could no longer arise abiotically.

Evolution of Prokaryotes into Eukaryotes

- The prokaryotes may have arisen more than ***3.5 billion years ago***.
- Eukaryotes may have evolved ***1.5 billion years ago***.

It is considered that prokaryotes converted into eukaryotes. Major change is development of organelles. Two hypotheses are considered in this context.

Endosymbiont Hypothesis

This hypothesis was presented by Lynn Margulis.

According to this hypothesis, eukaryotes and their organelles had been produced by some symbiotic relation with prokaryotes. Origin of some organelles has been described below.

SOLVED MDCAT

(i) Origin of Mitochondria

According to this hypothesis eukaryote cell might have evolved when large anaerobic amoeboid prokaryote ingested small aerobic bacteria and stabilized them instead of digesting them. This idea is known as the endosymbiont hypothesis.

These aerobic bacteria then converted into mitochondria, which are the sites of aerobic respiration and energy conversion in eukaryotic cells.

(ii) Origin of Flagella

Flagella (whip-like structure) might have evolved through the ingestion of prokaryotes similar to spiral-shaped bacteria (spirochetes).

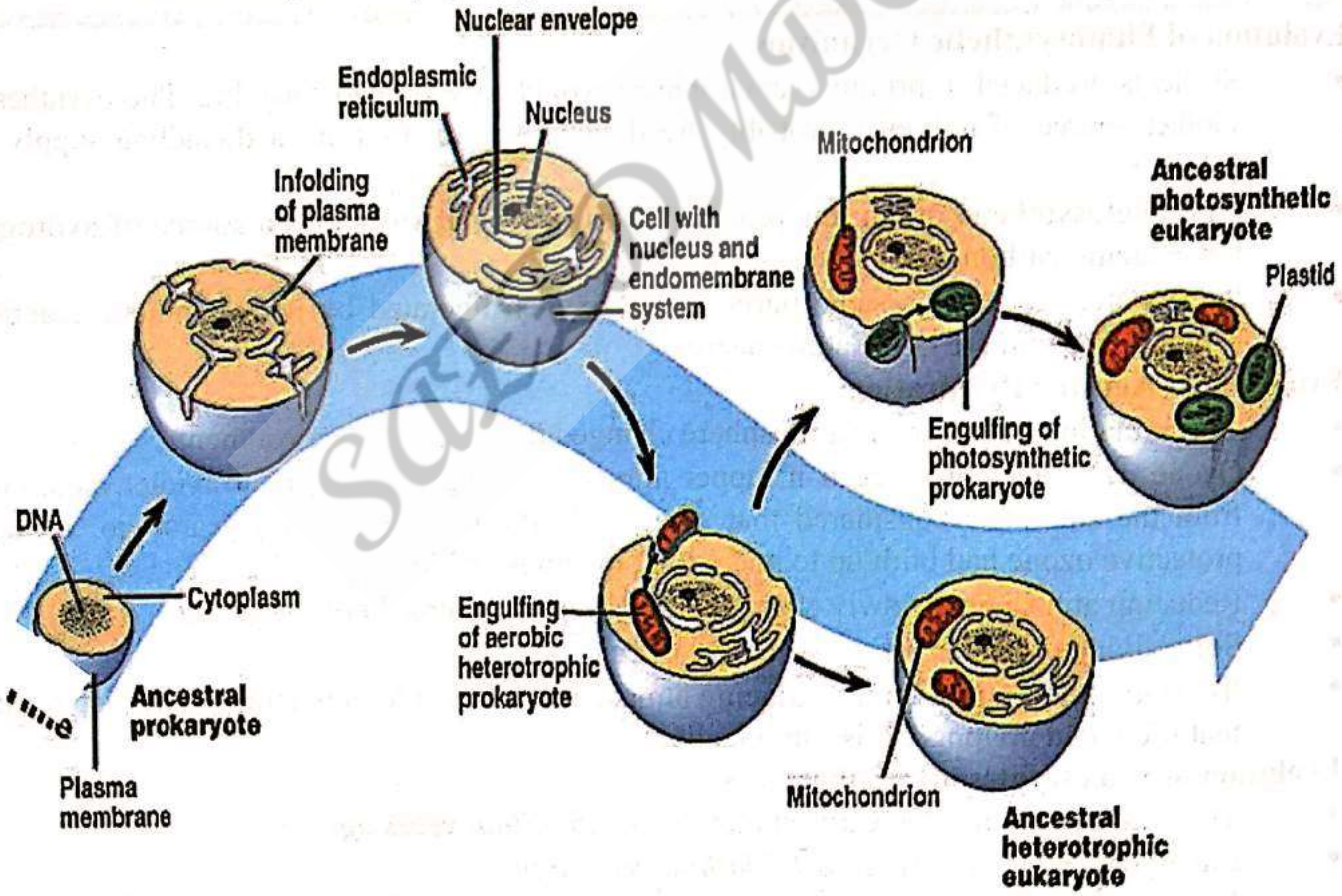
(iii) Origin of Chloroplast

Ingestion of prokaryotes that resembled present day cyanobacteria could have led to the endosymbiotic development of chloroplast in plants.

Cell Membrane Invagination Hypothesis

According to this hypothesis, cell membrane of prokaryotes invaginates (folded inward) to enclose copies of its genetic material.

This invagination resulted in the formation of several double membrane-bounded entities (organelles) in single cell. These entities could then have evolved into the eukaryotic mitochondrion, nucleus, chloroplast etc.



Evolution of Multicellular Eukaryotic Organism and Diversity

- Formation of eukaryotic cell led to a dramatic increase in the complexity and diversity of life forms on earth.
- During evolution, eukaryotic cell became specialized into tissues, which in turn formed organs for many different functions. These multicellular forms then adapted themselves to life in a great variety of environment.

CRITICAL THINKING

2. **Origin of life is explained by all except:**
 A. Endosymbiont hypothesis B. Creationism
 C. Hydrothermal vent hypothesis D. Chemical evolution

LAMARCKISM

Lamarck's Theory

- **Jean Baptiste Lamarck** (1744-1829) published his theory of evolution in 1809, the year Darwin was born.
- Two important points of **Lamarck's theory** are; use and disuse of organs and inheritance of acquired characters.
- Lamarck pictured evolution as ladder of life from simplest to complex organisms. Man was at top rung of the ladder.

Use and Disuse of Organs

- Lamarck argued that those parts of the body used extensively to cope with the environment become larger and stronger e.g. blacksmith developing a bigger biceps in the arm that works the hammer. Similarly, giraffe stretching its neck to new lengths in pursuit of leaves to eat.
- Those parts that are not used deteriorate e.g. loss of legs in snakes due to their habitat of burrows and bushes.

Inheritance of Acquired Characters

- According to Lamarck, inheritance of acquired characters means that the modifications an organism acquires during its lifetime can be passed along to its offspring e.g. the long neck of giraffe, Lamarck reasoned, evolved gradually as the cumulative product of a great many generations of ancestors stretching higher and higher.

Example: Evolution of Giraffe Neck

An example often used to illustrate Lamarck's hypothesis involves the evolution of the giraffe's long neck from short necked ancestors.

In Lamarckian terms, this process would have occurred as follows.

- Each giraffe, during its lifetime, would try to reach the leaves at the top of trees.
- Each animal would constantly stretch its neck in order to attain this goal.
- As these individuals reproduced, the results of neck stretching (an acquired characteristic) would be passed on to future generation.
- Each offspring would be born with a slightly longer neck than those of its parents. Thus, long necked giraffes gradually evolved.

Demerits of Lamarck's Theory

It has been now known that acquired characters cannot be inherited.

DARWINISM

- Darwin observed and collected thousands of specimens of diverse faunas and floras of South America.
- His main observations were about fauna and flora of Galapagos Islands where he collected 13 types of finches. He also observed saddle shaped shell tortoises. Tortoises on other islands were having dome shaped shell.

SOLVED MCQs

- According to Darwin, new species would arise from an ancestral form by the gradual accumulation of adaptations to different environments, separated from original habitat by geographical barriers. Over many generations, the two populations could become dissimilar enough to be designated as separate species.
- In 1844 Darwin wrote a long essay on the origin of species and natural selection, his book ***the origin of species*** was published in 1859.

Descent with Modification

- Darwin believed in ***perceived unity in life*** i.e. all organisms related through descent from some common ancestor that lived in the remote past.
- According to Darwin, history of life is like a tree, with multiple branching and re-branching from a common trunk all the way to the tips of the living twigs, symbolic of the current diversity of organisms.

Natural Selection and Adaptation

- Darwin suggested that populations of individual species become better adapted to their local environments through natural selection.
- Darwin's theory of natural selection was based on the following observations:

(i) Overproduction

Production of more individuals than the environment can support.

(ii) Variations

The individuals in a population exhibit variation in their traits. Some of these traits improve the chances of an individual's survival and reproductive success, whereas other traits do not.

(iii) Struggle for Existence

Struggle for existence among individuals of a population, with only a fraction of offsprings surviving each generation. Struggle for existence may be:

1. ***Intra-specific:*** Competition among organisms of same species.
2. ***Inter-specific:*** Competition among organisms of different species.
3. ***Environmental Struggle:*** Struggle against various environmental conditions.

(iv) Survival of the Fittest

It means survival in the struggle for existence is not random but depends in part on the heredity constitution of the surviving individuals. Those organisms whose inherited characteristics fit them best to their environment are likely to leave more offsprings than the less fit individuals.

(v) Evolution

This unequal ability of individuals to survive and reproduce will lead to a gradual change in a population, with favorable characteristics accumulating over the generations thus leading to the evolution of new species.

Neo-Darwinism

- Since natural selection was proposed, advances in genetics, biochemistry, ecology and paleontology have enabled scientists to identify mutation, genetic drift and gene flow as other natural forces of evolutionary change.
- The pioneering work of Cheverikov, Mayr, Simpson and many others led to what become known as the modern synthesis.
- ***Neo-Darwinism***, which emphasizes the ***role of genetics*** in explaining how evolution works. The modern theory accepts five major causes of evolution.

EVIDENCES OF EVOLUTION

Biogeography

- It is the geographical distribution of species.
- It was first evidence that suggested idea of evolution to Darwin.
- According to Darwin, islands have many species of plants and animals that are endemic but closely related to species of the nearest mainland or neighboring island.
- ***Armadillos*** (armored mammals) live only in America. The evolutionary view of biogeography predicts that contemporary armadillos are modified descendants of earlier species that occupied these continents and fossil records also confirm existence of such ancestors.
- Similarly, Darwin noticed that South America lacked rabbits, even though the environment was quite suitable to them. He concluded that there are no rabbits in South America because rabbits originated somewhere else and they had no means to reach South America.
- This distribution is due to geological barriers, harsh environmental conditions or presence of organisms that can compete.

Paleontology

- The succession of fossil forms is strong evidence in favor of evolution.
- It provides a visual record in a complete series showing the evolution of an organism.
 - ***Fossils*** are either the actual remains or traces of organisms that lived in ancient geological times.
- Most fossils are found in ***sedimentary rocks.***
- The oldest known fossils are of prokaryotes.
- They show chronological appearance of the different classes of vertebrate animals as shown by fossils. It shows following evolutionary arrangement:
 - Fishes → Amphibians → Reptiles → Mammals + Birds
- Sometimes, the fossil record allows us to trace the history of one particular organism, such as modern day horse *Equus*. The earliest horses had four toes. Over the time the number of toes reduced to three, in the modern horses to one, a large central toe that ends in a hoof. The evidences of fossil record support the common descent hypothesis.

CRITICAL CONCEPT!

Oldest Known Fossils:
The oldest known fossils, in fact, are of bacteria from Archaean rocks of Western Australia, dated 3.5 billion years old. This may be somewhat surprising, since the oldest rocks are only a little older: 3.8 billion years old.

CRITICAL THINKING

3. Bacterial fossils may be present in which form?

A. Humus
B. Cast as an impression
C. Spore
D. Petrified tissues

Comparative Anatomy

- Anatomical similarities between species grouped in the same taxonomic category bring another support to the theory of the descent with modification.
- Comparative anatomy supports that evolution is a remodeling process in which ancestral

structures that functioned in one capacity become modified as they take on new functions.

Homologous Structures

- Such organs, which are functionally different but structurally similar, are called homologous organs.
- Similarity in characteristics resulting from common ancestry is known as ***homology*** and such anatomical signs of evolution are called homologous structures.
- For examples, same skeletal elements make up the forelimbs of human, cats, whales, bats and all other mammals although they have different functions.
- The limb-bone pattern of all tetrapods from amphibian to mammals has the same structural plan. It is called ***pentadactyle limb***.

CRITICAL CONCEPT!

Interesting Fact:
At one point in time, whales walked on land!

- The basic similarity of these forelimbs is the consequence of the descent of all functions.
- The flower parts of a flowering plant are homologous. They are considered to have evolved from leaves, to form sepals, petals, stamens and carpels.
- They are considered to be evolved by ***divergent evolution***.

Analogous Structures

- Such organs, which are functionally alike but structurally different, are called analogous organs.
- They are considered to be evolved by ***convergent evolution***.
- For example, wings of birds and insects are examples of convergent evolution.

Vestigial Structures

- Such organs, which are historical remnants of structures that had important functions in ancestors but are no longer essential presently, are called vestigial organs.
- These are oldest homologous structures.
- For example, skeleton of whales and some snakes retain vestiges of the pelvis and leg bones of walking ancestors, vermiform appendix in carnivores, ear muscles in man etc.

CRITICAL CONCEPT!

Tail in Humans:
All humans develop a tail in the womb that eventually dissolves.

CRITICAL THINKING?

4. **This is a historical hypothesis that the development of the embryo of an animal, from fertilization to gestation or hatching, through stages resembling or representing successive adult stages in the evolution of the animal's remote ancestors:**
 A. Theory of natural selection
 B. Theory of modern synthesis
 C. Theory of catastrophism
 D. Theory of recapitulation

Molecular Biology

- The study of biochemical structures and functions of organisms at molecular level is called molecular biology.
- Evolutionary relationships among species are reflected in their ***DNA*** and ***proteins***, in their genes and gene products. If two species have genes and proteins with sequences of monomers that match closely, the sequences must have been copied from a common ancestor.

SCIED MDCAT

- Molecular biology provides strong evidence in support of evolution as the basis for the unity and diversity of life.

Examples

- A common genetic code brings evidence that all life is related.
- Humans and bacteria have some common proteins.
- ***Cytochrome 'c'***, a respiratory protein, is found in all aerobic species.

CRITICAL CONCEPT!

Junk DNA:
The term "Junk DNA" refers to regions of DNA that are noncoding or, in other words, they do not code for a protein.

CRITICAL THINKING

5. **It should not be present in *Spirochete*:**
 A. Cytochrome c
 B. Glucokinase
 C. Elongation factors
 D. Primase

CRITICAL CONCEPT!

One really extraordinary hint of evolution is actually found within our arms. There is a tendon that 10 – 15% of our human population has evolved out. This tendon is attached to an ancient muscle called the palmaris longus, which was primarily used by tree-dwelling apes (lemurs and monkeys, for instance) to help them move from branch to branch. Humans and ground-central apes, like gorillas, no longer have a need for this muscle or tendon, so both species have started to lose this internal function.

However, evolution is a slow-going process, so almost 90% of humans still have this useless trait carried down from our monkey ancestors.

To see if you have the tendon, lay your forearm down on a table, palm up. Touch your pinky to your thumb and lift your hand just a little off the surface. If you see a raised band in the middle of your wrist, you have the tendon connected to your still-intact palmaris longus.

If you don't – congrats, you're evolving.



SCIENCE WORLD

TOPIC-9 LIFE PROCESSES IN ANIMALS & PLANTS

COURSE CONTENT

Nutrition

- Modes of Nutrition
- Carnivorous Plants
- Digestive system

Gaseous Exchange / Respiratory system

Transport

- Uptake and Transport of Minerals and Water
- Uptake of Water by Roots
- Water Potential
- Ascent of sap
- Translocation of Organic Solutes

Cardiovascular system

- Structure of Human Heart
- Blood Vessels

Lymphatic System

Immune System

NUTRITION

MODES OF NUTRITION

Organisms can be divided into two classes on the basis of their method of nutrition.

AUTOTROPHS	HETEROTROPHS
Autotrophic organisms can exist in an exclusively inorganic environment because they can manufacture their own organic compounds from the inorganic raw material taken from the surrounding media. This means that they produce their own sugars, lipids, proteins etc. from carbon dioxide, water and nitrates	Heterotrophic organisms are incapable of manufacturing organic compounds from simple inorganic nutrients and so they obtain organic molecules from the environment in the form of food
Example: Plants, Algae, Some bacteria.	**Example:** Animals, Fungi

CARNIVOROUS PLANTS

- There are a few plants that supplement their inorganic diet with organic compounds.
- These organic compounds are obtained by trapping and digesting insects and small animals. All of the insectivorous plants are ***true autotrophs***, but when they capture prey, their growth becomes rapid.
- Apparently, nitrogenous compounds of animal body are of benefit to these plants. In some plants, the trapped insects are decomposed by bacteria.

SOLVED MDCAT

- In others, the trapped insects are ***digested by enzymes secreted by the leaves***. The plants absorb the nitrogenous compounds thus formed.

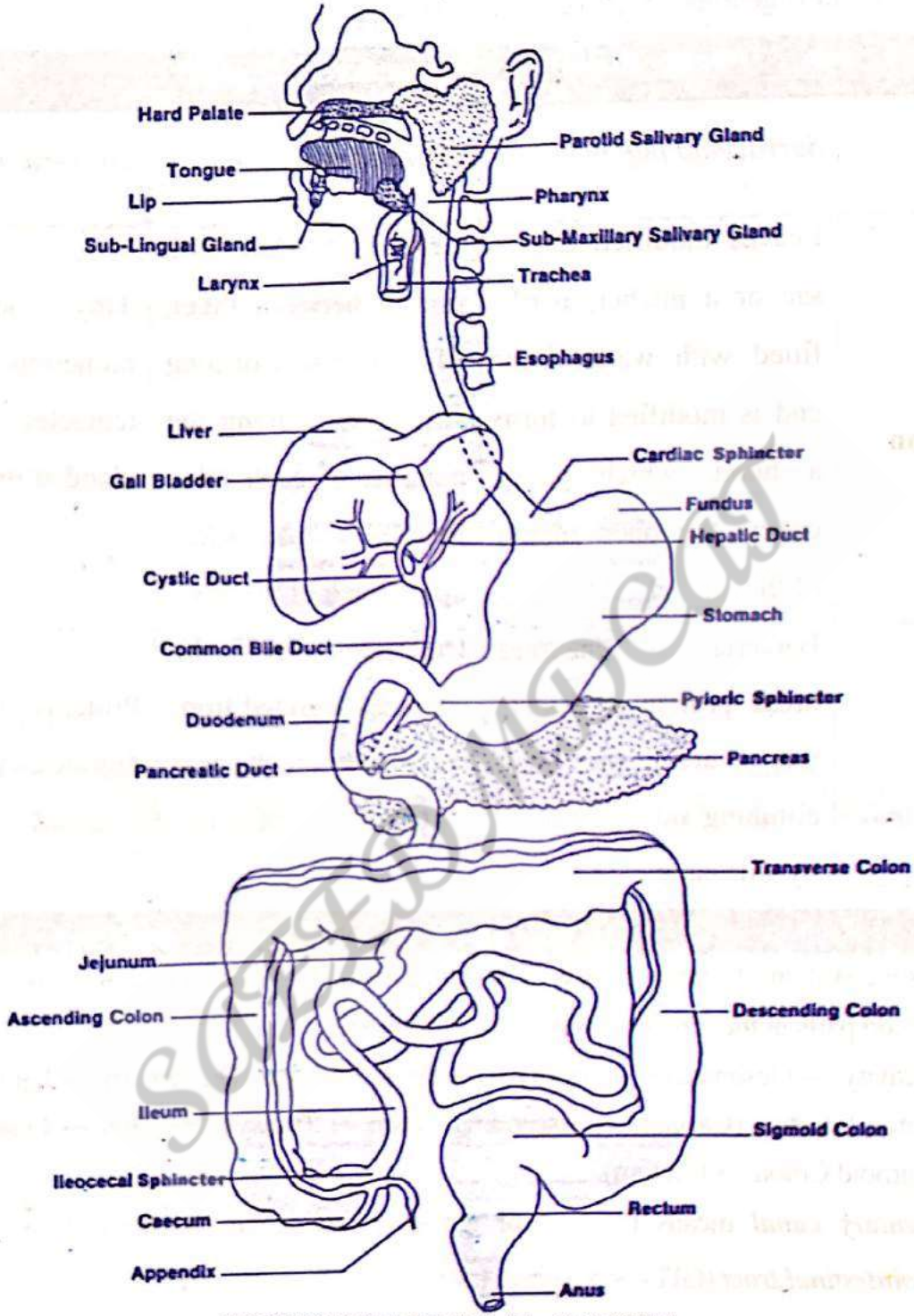
	Pitcher Plant	Venus-Fly Trap	Sundew
Scientific Name	*Sarracenia pupurea*	*Dionaea muscipula*	*Drosera intermedia*
Leaf Modification	Leaves modified into a sac or a pitcher, partly filled with water. Leaf end is modified to form a hood, which partly covers the open mouth of the pitcher	Leaf is bilobed with midrib between them. There is a row of long stiff bristles along the margins of each lobe. Bristles interlocked upon touch of insects	Tiny leaves bear numerous hair like tentacles, each with a gland at its tip
Digestion	Bacteria or enzymes break protein of insects that are prevented climbing out of pitcher by stiff hairs	Digestion by the enzymes secreted from the glands on the leaf surface	Proteins of insects are digested by enzymes

DIGESTIVE SYSTEM

- Digestive system of a man consists of structures extending from mouth to anus (tube like)
- The main parts in the direction of passage of food are:
 Oral cavity → Oesophagus → Stomach → Small Intestine (Duodenum → Jejunum → Ileum) → Large Intestine (Caecum → Ascending Colon → Transverse Colon → Descending Colon → Sigmoid Colon → Rectum)
- ***Alimentary canal*** means the part of gut from oral cavity to anus. It is also called as ***gastrointestinal tract*** (GIT) or digestive tract.
- ***Digestive system*** means alimentary canal plus associated glands.
- Associated glands are salivary glands, liver and pancreas.
- Digestion occurs at three main sites:

Parts	Chemical Digestion	Mechanical Digestion
Oral Cavity	Amylase	Teeth
Stomach	Gastric Juice	Grinding
Small intestine	Pancreatic & Intestinal Juice	Emulsification

HUMAN DIGESTIVE SYSTEM



DIGESTION IN ORAL CAVITY

Oral Cavity

It is the site for entrance of food in alimentary canal.

Overall Functions of Oral Cavity

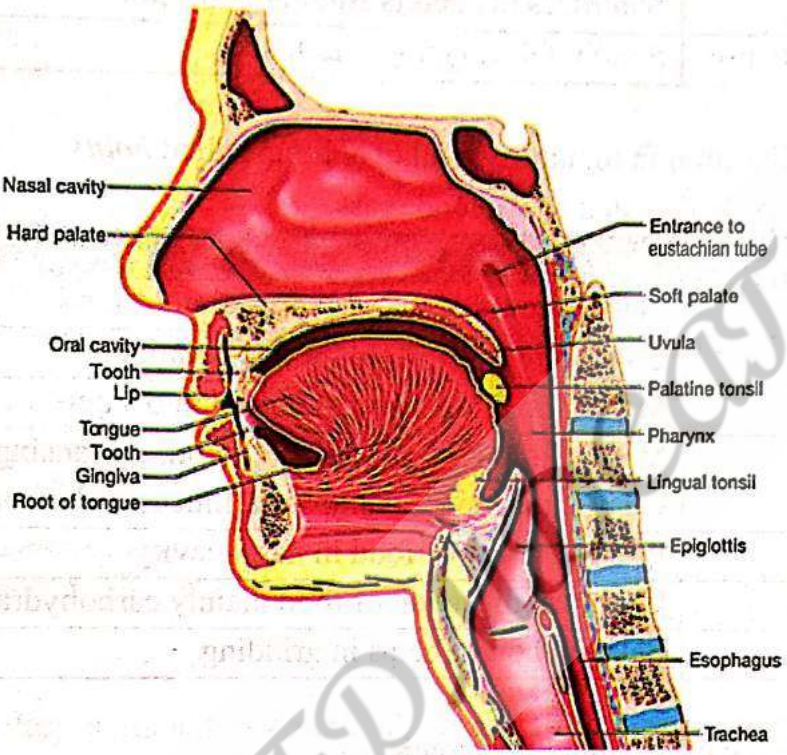
It performs four important functions:

- Selection of Food
- Grinding or Mastication
- Lubrication
- Digestion

Structures Associated with Oral Cavity

Oral cavity is bounded by:

- Palate
- Tongue
- Teeth
- Cheeks



Selection of Food

- When food enters in oral cavity, it is tasted, smelled and felt.
- Oral cavity is aided in selection by the senses of smell and sight.
- Tongue being sensory and muscular organ plays the most important role in the selection of food through its taste buds.

Grinding or Mastication

- Food is ground by means of molar teeth.
- This grinding is useful because:

(a) Oesophagus allows relatively small pieces to pass through.

(b) Small pieces have much more surface for enzymes to attack.

Lubrication & Digestion

These are main functions of oral cavity accomplished by saliva. Saliva is secreted by three pairs of salivary glands:

Salivary Glands

- Three pairs of salivary glands are:

Glands	Location	Secretions	Opening of Ducts
Parotid glands (Largest)	In front of ears	Saliva with amylase	Posterior part of oral cavity
Submandibular/ Sumaxillary glands	Behind jaws	Saliva with amylase & mucus	Floor of oral cavity
Sublingual glands (Smallest)	Below tongue	Saliva with mucus only	Floor of oral cavity

Saliva

- Fresh saliva is alkaline with pH nearly 8, quickly loses carbon dioxide and gets to pH 6.
- It has three major components:

Components	Role
Water and Mucus (GP)	Moisten and lubricate food
Sodium bicarbonate	Stabilizes pH and is slightly antiseptic
Salivary Amylase/ Ptyalin	Starch/ Glycogen → Maltose

End Result Bolus

- End result of digestion in mouth is small oval lump called ***bolus***.
- It is softened, partly digested slimy food mass.

Anatomy of Oral Cavity	Physiology of Oral Cavity
Teeth	Mastication/ Mechanical digestion of food
Lips	Communication, Hold food in position
Jaws	Mastication/ Mechanical digestion of food
Tongue	Manipulation of food, hold food, Cleansing of teeth, Taste, Communication, Swallowing, mucus and serous
Soft Palate	Prevents entry of food in nasal cavity
Salivary Glands	Chemical digestion of food mainly carbohydrates
Hard Palate	Palatine bones, helps in grinding

PHARYNX

- The pharynx is a cavity behind the mouth.
- It is common passage for digestive system and respiratory system.
- It is lined by mucus.

SWALLOWING

- Transfer of bolus from buccal cavity to pharynx and then to oesophagus is called ***swallowing / deglutition***.
- Beginning of swallowing is voluntary action and then it becomes involuntary. The swallowing procedure is regulated by nerves in the medulla oblongata and pons.

Events of Swallowing

(i) Tongue moves upwards and backwards against the roof of mouth, forcing the bolus to the back of the mouth cavity.

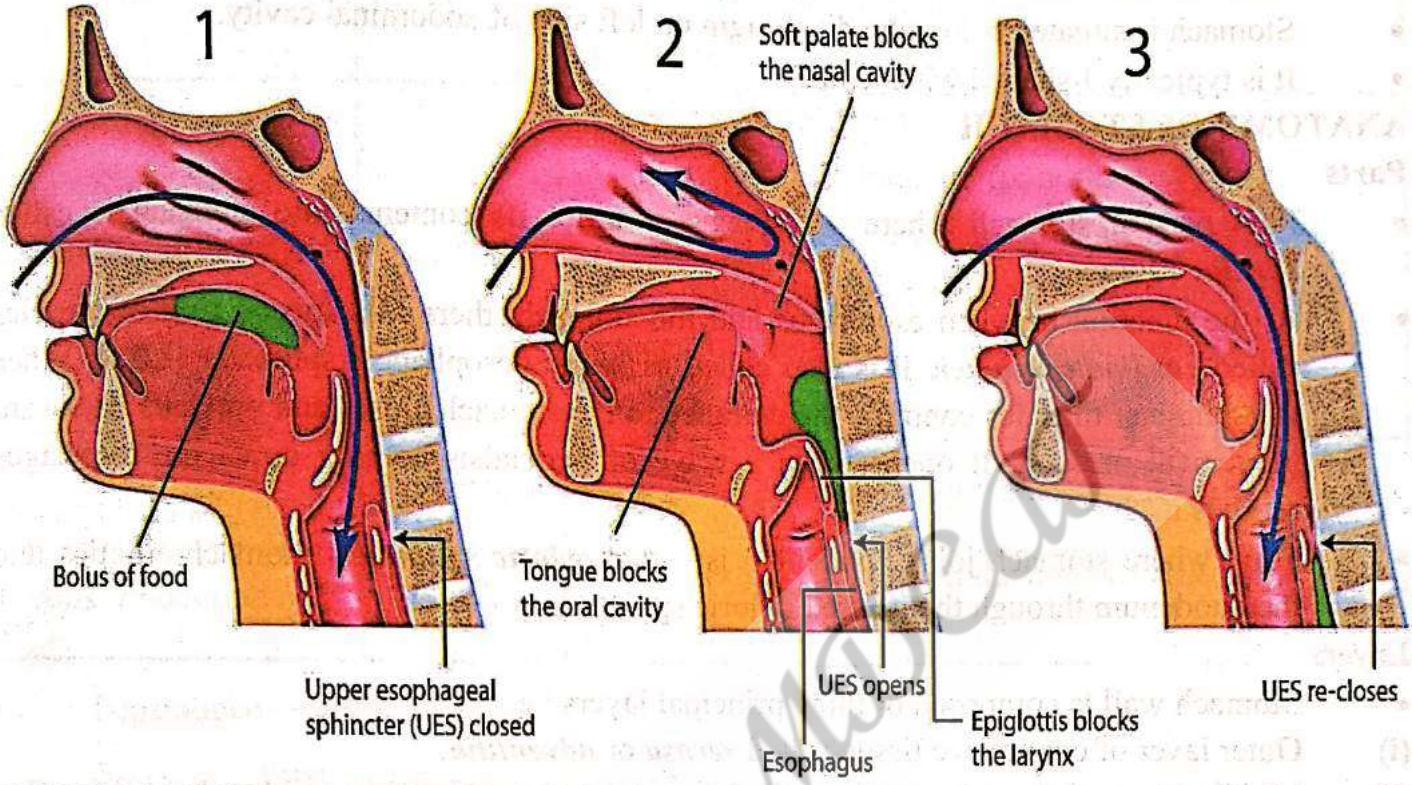
(ii) Soft palate is pushed up by tongue which closes nasal cavity.

(iii) Tongue forces the epiglottis (flap of cartilage) into more or less horizontal in position thus closing the opening of windpipe (glottis). Epiglottis diverts the bolus toward oesophagus.

(iv) The larynx (cartilage box round the top of windpipe) moves upward under the back of tongue.

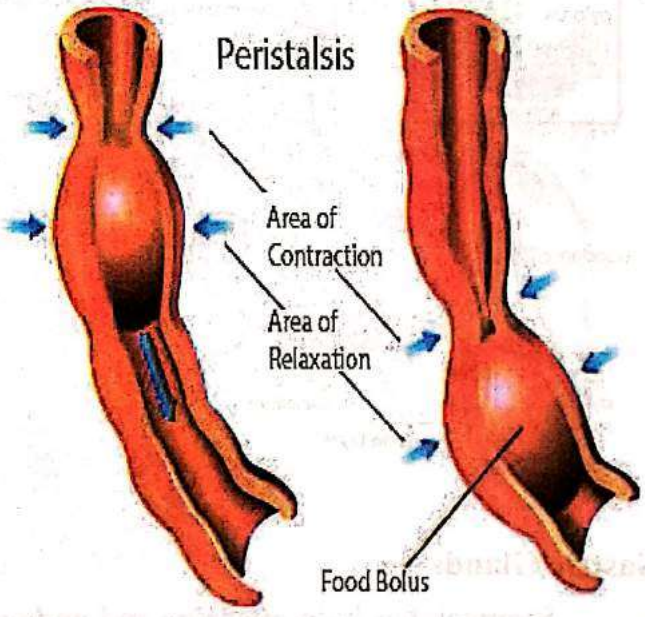
(v) The glottis is partly closed by the contraction of ring of muscles.

Swallowing



PERISTALSIS

- ***Peristalsis*** is characteristic movement of digestive tract due to alternate contractions and relaxations of smooth muscles by which food is pushed along the digestive tract.
- It consists of the wave of contraction of circular and longitudinal muscles preceded by the wave of relaxation thus squeezing the food down along the canal.
- Relaxation of circular muscles in front of food is followed by a wave of strong contraction of circular muscles behind food.
- Peristalsis starts just behind the mass of food, from the buccal cavity, along the oesophagus to the stomach and then along the whole alimentary canal.
- ***Antiperistalsis*** are reverse peristaltic movements due to which food is passed from intestine back into stomach and even in mouth. It may lead to vomiting.
- Hunger contractions are peristaltic contractions caused by low blood glucose level. These create an uncomfortable sensation often called ***hunger pangs***.
- Hunger pangs usually begin 12-24 hours after the previous meal.



- ***Gravity*** assist the movement of material through the oesophagus, especially when liquids

DIGESTION IN STOMACH

Introduction

- Stomach is an elastic muscular bag.
- Stomach is situated below the diaphragm on left side of abdominal cavity.
- It is typically J-shaped when empty.

ANATOMY OF STOMACH

Parts

- First part of stomach where oesophagus empties its contents into stomach is called ***cardiac region***.
- At the junction between esophagus and the stomach, there is a special ring of muscles called ***cardiac sphincter.*** It is also called as lower oesophageal sphincter (LES). When the sphincter muscles contract, the entrance to the stomach closes and prevents backward movement of food. It opens when a wave of peristalsis coming down the esophagus reaches it.
- Point where stomach joins duodenum is called ***pyloric sphincter***. Stomach empties into the duodenum through the relaxed pyloric sphincter.

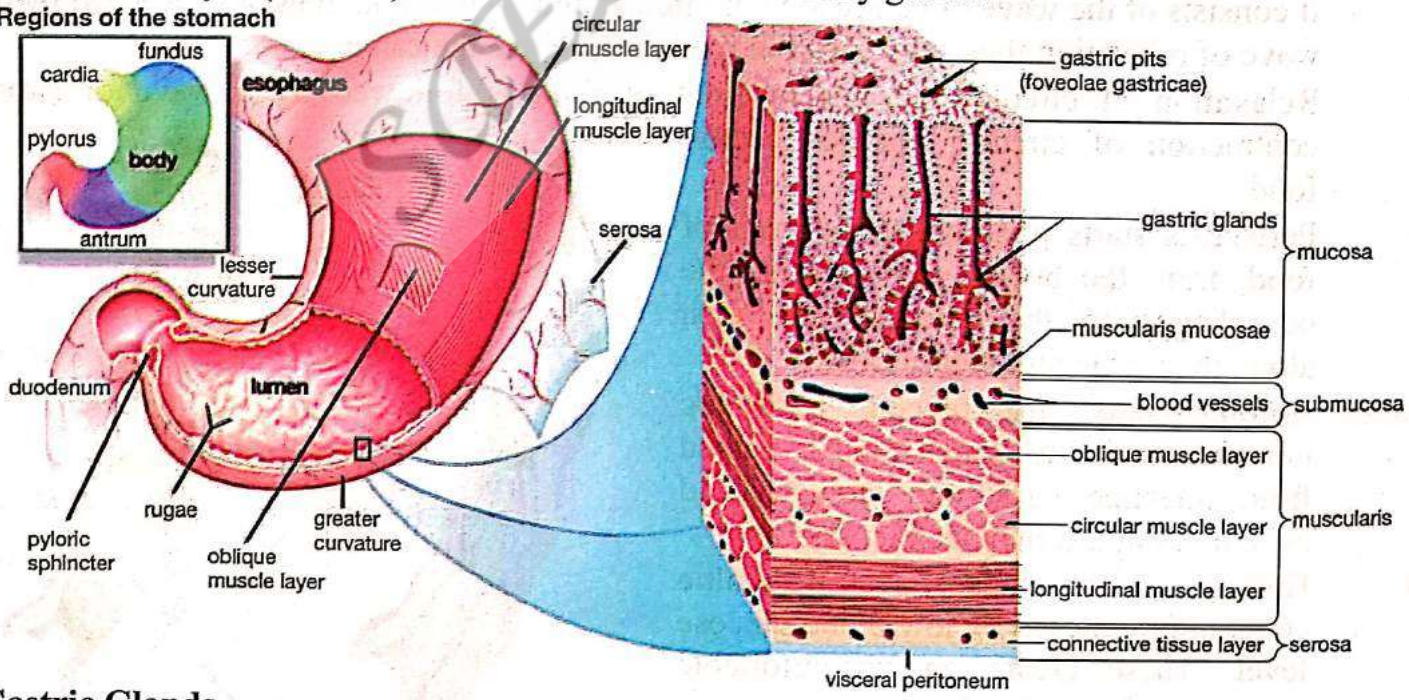
Layers

- Stomach wall is composed of three principal layers i.e.

(i) Outer layer of connective tissue called ***serosa*** or ***adventitia***.

(ii) Middle layer of smooth muscles called ***muscularis externa*** along-with submucosa. This muscular layer has innermost oblique muscles, middle circular and outer longitudinal muscles.

(iii) Inner layer (***mucosa***) of connective tissue with many glands.



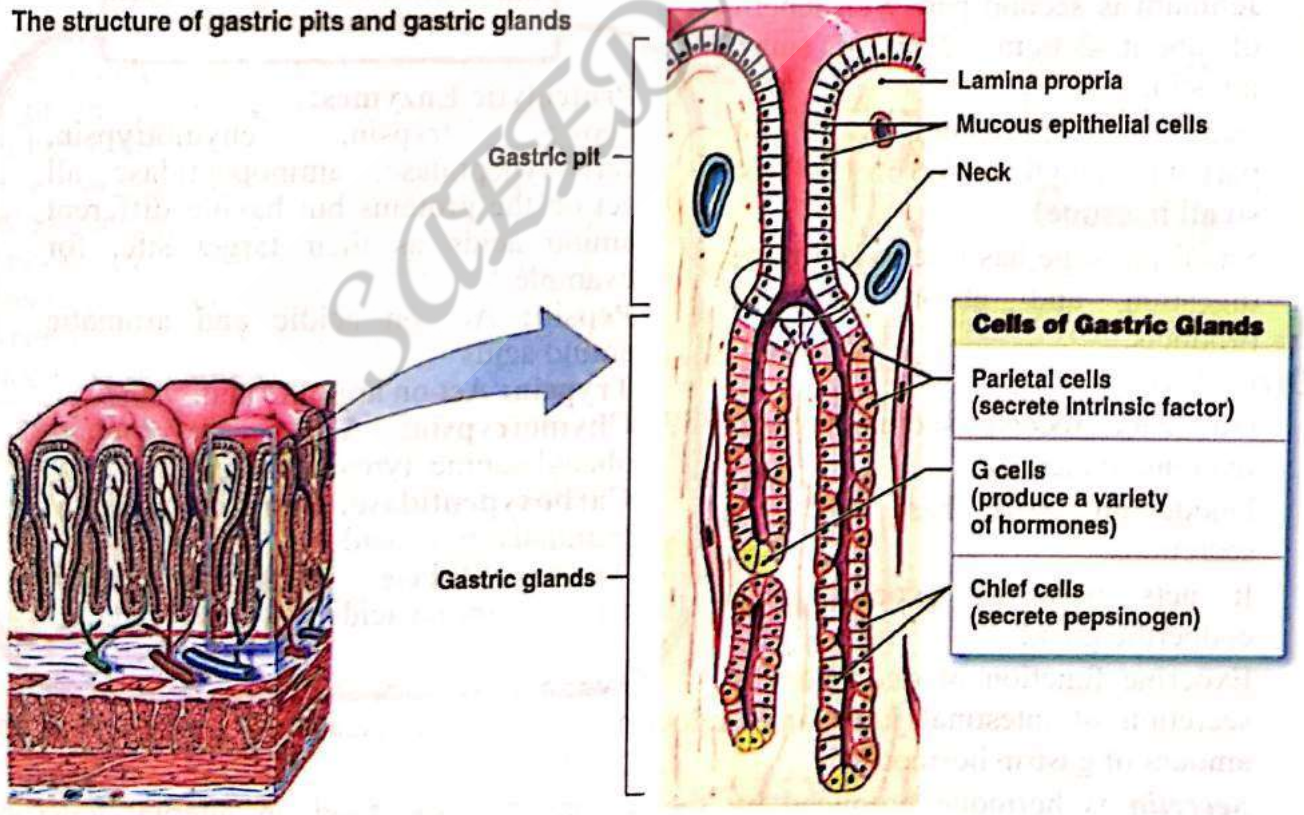
Gastric Glands

- Stomach has both ***exocrine*** and ***endocrine glands***. Exocrine glands secrete gastric juice while endocrine secrete gastrin hormone.

Cells	Secretions	Functions
Mucous cells	Mucus	• Thick secretion • Covers inside of stomach • Protects stomach wall
Parietal/Oxyntic cells	HCl	• Maintains pH from 2-3 • Provide acidic medium for enzymes • Softens food & kills microorganisms • Converts inactive pepsinogen into pepsin • Inactivates salivary amylase • Low pH denatures many proteins
Zymogen/ Chief/ Principal cells	Pepsinogen	Hydrolyzes proteins into peptones and polypeptides.
G cells/ Endocrine cells	Gastrin	Stimulates gastric juice production, secretion & stomach motility

- Pepsinogen $\xrightarrow[\text{Pepsin}]{\text{HCl}}$ Pepsin
- Proteins $\xrightarrow{\text{Pepsin}}$ Polypeptides & Peptones

The structure of gastric pits and gastric glands



Regulation of Gastric Juice Production

- Both nervous and hormonal mechanisms regulate gastric secretions.
- Gastric juice secretion is regulated by small, sight and quality of food.

SCIENCEMDCAT

- Main hormones that regulate gastric secretions are gastrin and secretin.
- If more protein is present in food, it stimulates production of gastrin hormone from gastric endocrine lining of pyloric region of stomach.
- More protein → More gastrin → More gastric juice

PHYSIOLOGY OF STOMACH

1. Food Storage

- It stores food from meals for some time, making discontinuous feeding possible.

2. Digestion of Food

- It partly digests protein food.
- Stomach shows both chemical and mechanical digestion. Mechanical digestion is carried out by middle muscular layer and is called ***churning***. While chemical digestion is carried out by gastric glands.
- Muscular walls thoroughly mix up the food with gastric juice.
- End result of digestion in stomach is formation of semi-solid mass called ***chyme*** (semi solid.

3. Absorption

- Some absorption also occurs at stomach.

4. Defense/ Immunity

- Mucous membrane and HCl act as barriers against germs.

DIGESTION IN SMALL INTESTINE

- It is the longest part of alimentary canal.
- There are three parts of small intestine i.e. duodenum, jejunum and ileum.
- Duodenum is first & the shortest part of small intestine and is about 20-25 cm long.
- Jejunum is second part with length of about 2.4 m ($2/5^{th}$ of small intestine)
- Ileum is the third and the longest part with length of 3.6 m ($3/5^{th}$ of small intestine).
- Small intestine has role to complete digestion and absorb digested products.

CRITICAL CONCEPT!

Proteolytic Enzymes:
Pepsin, trypsin, chymotrypsin, carboxypeptidase, aminopeptidase all act on the proteins but having different amino acids as their target site, for example
Pepsin: Act on acidic and aromatic amino acids
Trypsin: Act on arginine and lysine
Chymotrypsin: Act on tryptophan, phenylalanine, tyrosine, leucine
Carboxypeptidase: Carboxyl group of terminal amino acids
Aminopeptidase: Amino group of terminal amino acids

DUODENUM

- Duodenum receives secretions from liver and pancreas.
- Duodenum also has its own secretions.
- It acts both as exocrine and endocrine gland.
- Exocrine function of duodenum is secretion of intestinal juice and endocrine function is release of secretin and small amount of gastrin hormone.
- ***Secretin*** is hormone produced by the action of acidic food on internal mucosa of duodenum. It inhibits production of gastric secretions and promotes production of secretions of liver and pancreas.

- Chyme after neutralization by secretions from liver, pancreas and duodenum is called ***chyle*** (liquid).

Pancreas

- Pancreas is also a large ***dual gland.***
- Pancreatic juice is produced by exocrine part of pancreas, which is poured in duodenum by pancreatic duct.
- Endocrine part of pancreas produces hormones insulin and glucagon.

Components of Pancreatic Juice

Component	Role
Amylase (amylopsin)	Carbohydrate digesting enzyme (Starch/Glycogen → Maltose)
Lipase	Fat digesting enzyme (Fats → Fatty acids + Glycerol)
Trypsin	Protein digesting enzyme (Proteins → Polypeptides + Peptones)
Chymotrypsin	Protein digesting enzyme (Proteins → Polypeptides + Peptones)
Sodium bicarbonate	Neutralizes chyme, provides alkaline medium

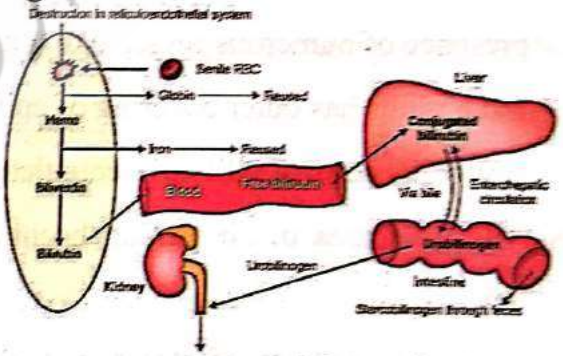
- Trypsin is secreted as inactive trypsinogen, which is activated by enterokinase, an enzyme secreted by the lining of duodenum.
- Chymotrypsin is secreted as inactive chymotrypsinogen, which is activated by trypsin.

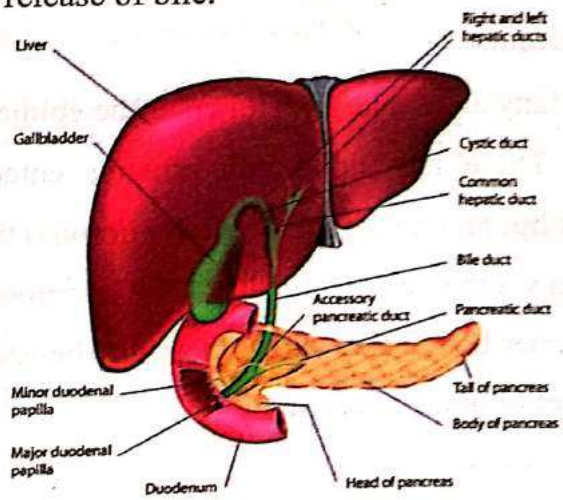
Liver

- Bile is produced in liver, stored in gall bladder, acts in small intestine.
- Bile is transported from liver to gall bladder then to small intestine through bile duct.
- Bile is green, watery fluid containing salts and ***no enzyme.***
- Green colour of bile is due to bile pigments produced due to breakdown of hemoglobin.
- Bile salts emulsify fats i.e. converts it into small globules.
- These small globules are easily digested by water soluble lipase.
- Accumulation of bile pigments in blood causes ***jaundice.***
- Cholesterol secreted by liver may precipitate in the gall bladder to produce ***gall stones***, which may block the release of bile.

CRITICAL CONCEPT!

Formation and Circulation of Bile Pigments:





JEJUNUM AND ILEUM

- Jejunum and ileum are involved in complete digestion of food.

Enzymes of Intestinal Lining

Enzymes	Substrates	Products
Amino peptidase	Polypeptides	Dipeptides
Erypsin	Dipeptides	Amino acids
Lipase	Fats	Fatty acids & glycerol
Maltase	Maltose	Glucose
Lactase	Lactose	Glucose & galactose

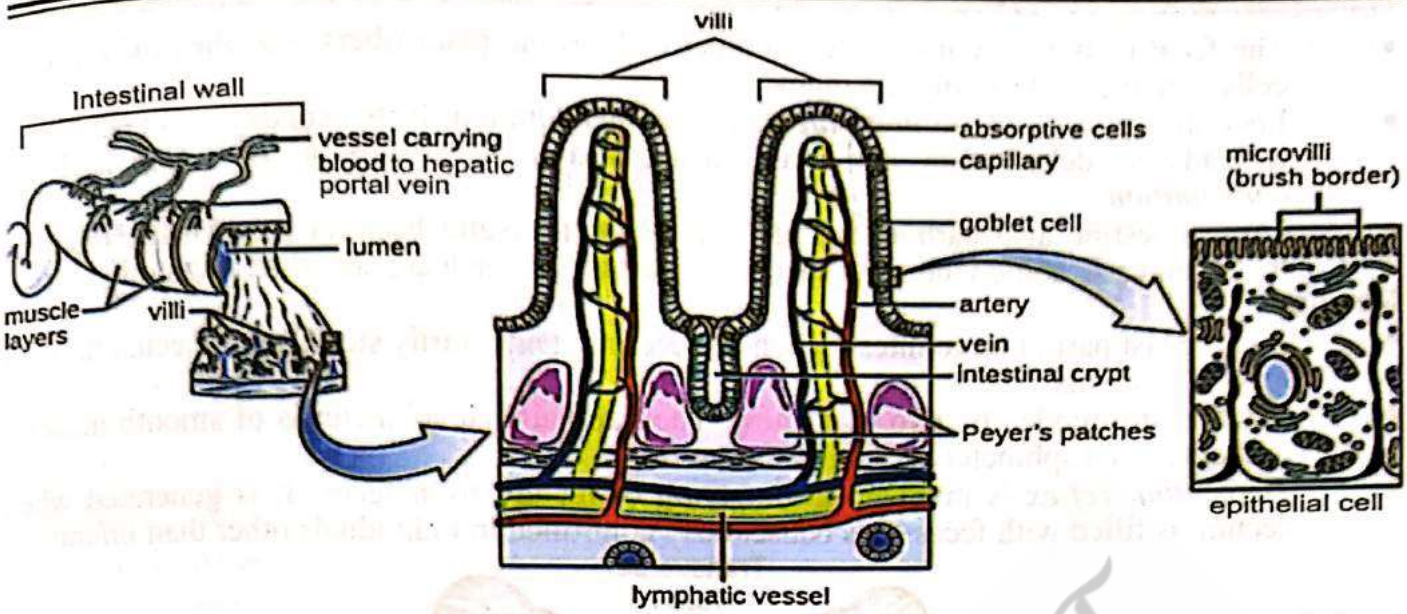
CRITICAL THINKING

1. **A protease which is protein in nature:**
 A. Lipase B. Enterokinase
 C. Gastrin D. Amylase
2. **Which of the following glandular secretions involved in digestion would be most likely released initially as inactive precursors?**
 A. Protein-digesting enzymes B. Fat-solubilizing bile salts
 C. Acid-neutralizing bicarbonate D. Carbohydrate-digesting enzymes

Absorption of Food

- Internal surface of ileum has many folds, which exhibits velvety appearance due to the presence of numerous finger-like outgrowths called ***villi***.
- Each villus has outer covering of epithelial cells, blood capillaries and ***lacteals***.
- Epithelial cells of villi have countless, closely packed cylindrical processes, ***microvilli***.
- The total area of absorption becomes incredibly large due to the infoldings, villi and microvilli.
- The end products of starch and glycogen, which is glucose, and the end product of proteins (amino acids) are absorbed into blood capillaries of villi by diffusion or active transport. Some of the fatty acids and glycerol (end products of lipid breakdown) are also absorbed into blood stream.
- A large proportion of fatty acids and glycerol enter the epithelial cells of villi, where they recombine into fats. These fats along-with proteins enter into the lacteals and are transported in form of lipoproteins droplets (***chylomicrons***) through lymph vessels. These pass into blood stream via thoracic lymph duct. The lipoproteins are hydrolyzed by blood plasma enzyme and enter body cells, where they may be used in respiration or stored as fat in the liver, muscles or under the skin.

SCIENCE MDCAT



CRITICAL THINKING

3. **To leave the digestive tract, a substance must cross a cell membrane. During which stage of food processing does this take place?**
 A. Ingestion B. Digestion
 C. Hydrolysis D. Absorption
4. **Most nutrients absorbed into the lymph or bloodstream are in which form?**
 A. Disaccharides B. Polymers
 C. Monomers D. Enzymes
5. **Which of the following is a nutritional monomer that can be transported in the blood?**
 A. Sucrose B. Maltose
 C. Alanine D. Dipeptide

End Result

- After absorption, the intestinal contents are pushed along the alimentary canal by normal peristaltic activity.
- At the end of ileum, there is an ***ileocolic/ileocecal sphincter*** that transfers residues to large intestine.

LARGE INTESTINE

- Large intestine is last part of alimentary canal.
- It is divided into caecum, colon and rectum.

Caecum

- ***Caecum*** is a blind sac that projects from the large intestine between ileum and colon.
- Finger-like appendix arises from the blind end of caecum. Inflammation of appendix is called ***appendicitis***.

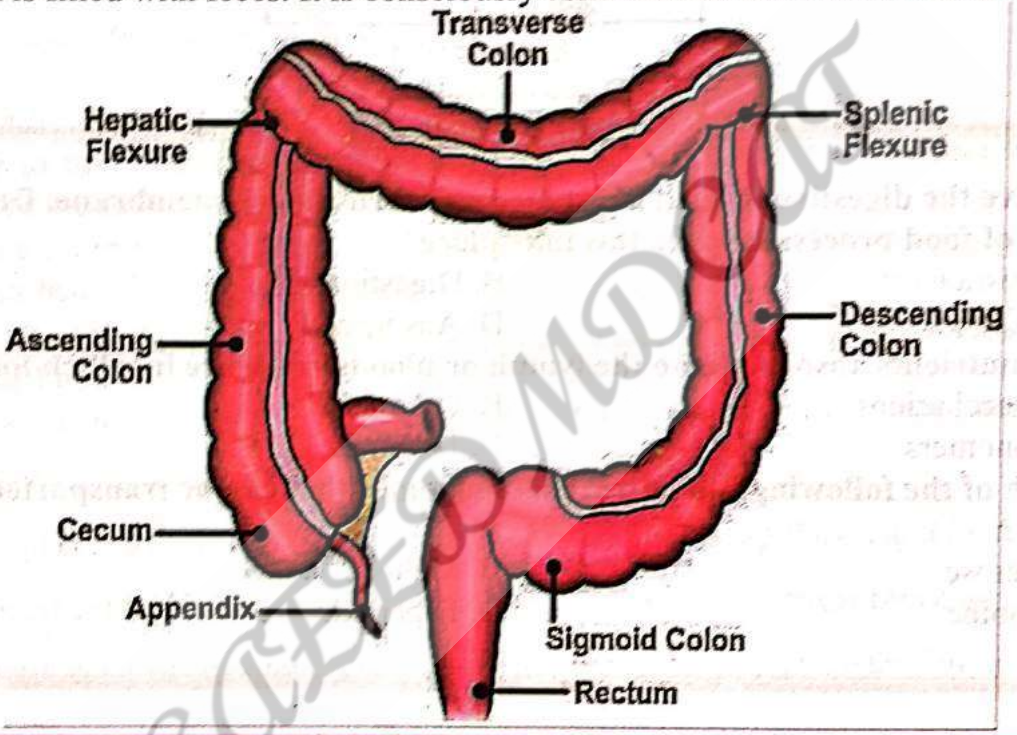
Colon

- ***Colon*** is longest part of large intestine. It is further divided into ascending, transverse, descending and sigmoid colon.
- The material that pass from small intestine to large intestine contain a large amount of water, dissolved salts and undigested material.
- Large intestine is involved in absorption of water and salts while undigested material is rejected as feces.

- The fecal matter contains a large number of bacteria, plant fibers, sloughed off mucosal cells, mucus, cholesterol, bile pigments and water.
- Less absorption leads to ***diarrhoea*** and then dehydration. If this condition is unchecked, it leads to dehydration and even death. Excessive absorption of water leads to ***constipation***.
- Large intestine also harbors a large population of useful bacteria (mutualistic relation) that synthesize some vitamins especially vitamin K, which are absorbed in blood.

Rectum

- It is the last part of large intestine where feces are temporarily stored and rejected through anus at intervals.
- Anus is surrounded by two sphincters. The internal anal sphincter is of smooth muscles and outer anal sphincter is of striped muscles.
- ***Defecation reflex*** is involved in emptying of rectum from feces. It is generated when rectum is filled with feces. It is consciously controlled in individuals other than infants.



GASEOUS EXCHANGE / RESPIRATORY SYSTEM

ANATOMY OF HUMAN RESPIRATORY SYSTEM

Human respiratory system includes:

1. Air Passage Way
2. Lungs

Air Passage Way

- It is passage way by which air enters or leaves the lungs.
- It consists of following components in sequence:
 Nostrils → Nasal Cavities → Pharynx → Larynx → Trachea → Bronchi → Terminal Bronchioles → Respiratory Bronchioles → Alveolar Ducts → Alveolar Sacs

Components	Anatomy	Physiology
Nostrils (2)	• Bone & cartilage • Hair • Mucous membrane	• Filtration of larger particles. • Moistening • Warming
Nasal Cavities (2)	• Each cavity subdivided into 3 passage	• Filtration

	ways. • Ciliated epithelium • Mucous membrane	• Moistening • Warming
Pharynx/ Throat	• Muscular passage • Mucous membrane	• Channelizes air to larynx
Larynx/ Voice box	• Cartilaginous box • Glottis • Epiglottis • Vocal cords	• Air passage way • Voice production
Trachea/ Windpipe (1) (ventral to oesophagus)	• C-shaped cartilage rings • Ciliated epithelium • Mucous cells/ Goblet cells	• Air passage way • Filtration • Moistening
Primary Bronchi (2)	• C-shaped cartilage rings • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening
Secondary & Tertiary Bronchi	• Irregular cartilage plates • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening
Terminal Bronchioles	• Diameter of 1 mm or less • No cartilage • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening
Respiratory Bronchioles	• No cartilage • No Ciliated epithelium • Mucous cells	Gaseous exchange with blood
Alveolar Ducts & Alveolar Sacs	• Single layered surrounded by blood capillaries • Lined by surfactant	Gaseous exchange with blood

CRITICAL THINKING

6. Which of the following features do all gas exchange systems have in common?

A. The exchange surfaces are moist
B. They are enclosed within ribs
C. They are maintained at a constant temperature
D. They are exposed to air

- Epiglottis is cartilaginous lid having a muscularly controlled, hinge-like action.
- Vocal cords are two thin edged stretched fibrous bands. These are larger in male so male have low pitched voice.
- Cartilage in air passage way prevents collapse.
- Bronchioles are made up of mainly circular smooth muscles. Change in diameter is possible through bronchioles.
- Air sac is the functional unit of lungs.

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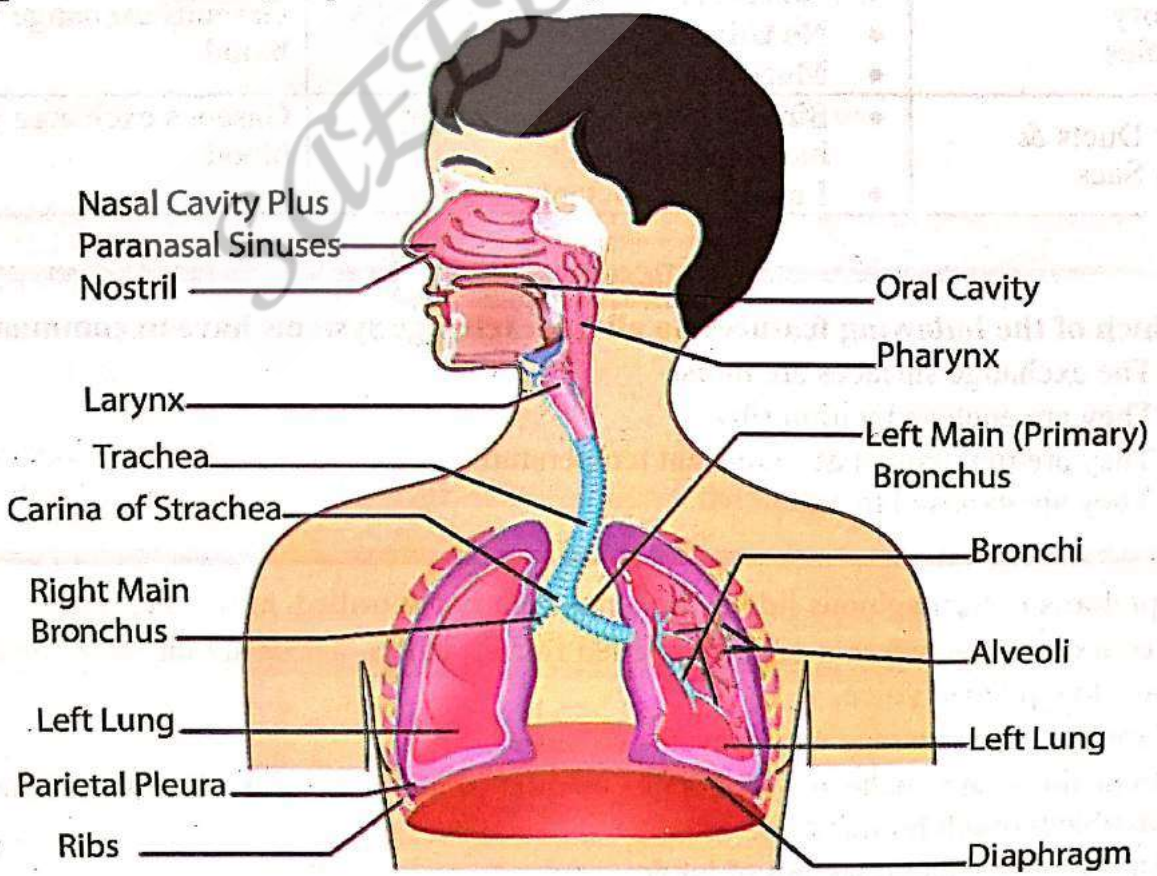
Components	Cartilage	Ciliated epithelium with goblet cells	Smooth muscles	Elastic fibers
Trachea	✓	✓	✓	✓
Bronchi	✓	✓	✓	✓
Terminal Bronchiole	×	✓	✓	✓
Respiratory Bronchiole	×	×	✓	✓
Alveolar Duct	×	×	✓	✓
Alveolar Sac	×	×	✓	✓

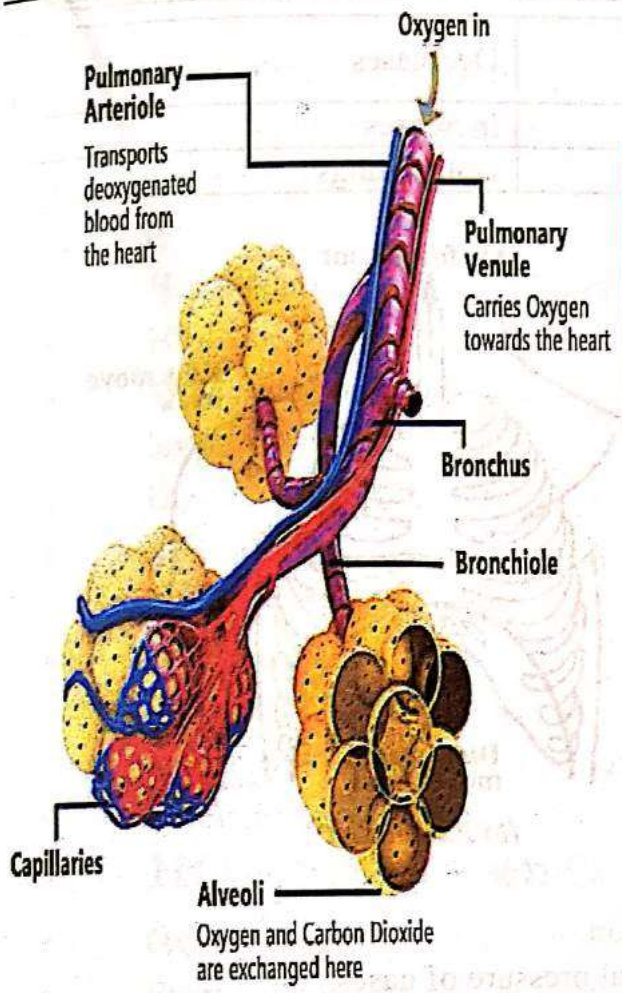
Lungs

- They are closed sacs that are connected to the outside by the way of trachea and nostrils or mouth.
- The right and left lungs are slightly unequal in size.
- Lungs are spongy because of presence of millions of alveoli.
- Lungs are placed in the chest cavity.
- Chest cavity is bounded by ribs and intercostal muscles on the sides.
- The floor of the chest is called diaphragm. Diaphragm is a sheet of skeletal muscles.
- Lungs are covered by a double layered thin membranous sac called ***pleura***.

Surfactant

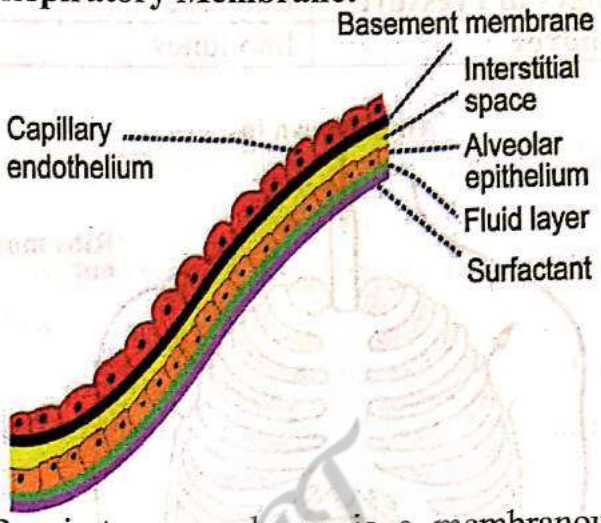
- Mixture of lipoproteins secreted by alveolar epithelium
- Forms a layer over the surface of the fluid within the alveoli to reduce surface tension
- In premature infants, respiratory distress syndrome is common due to its deficiency





CRITICAL CONCEPT!

Respiratory Membrane:



Respiratory membrane is a membranous structure through which exchange of respiratory gases takes place. It is formed by Epithelium of respiratory unit and Endothelium of pulmonary capillary. Epithelium of respiratory unit is a very thin layer.

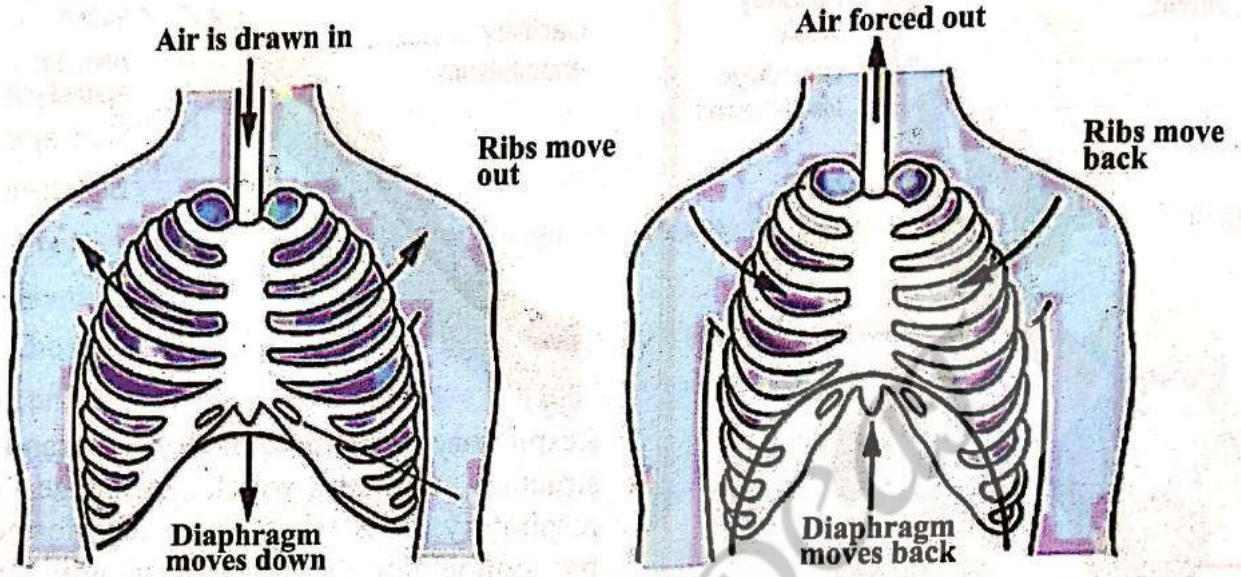
BREATHING

- Breathing is a process by which fresh air containing oxygen is pumped into the lungs and air with more carbon dioxide is pumped out of lungs.
- It has both voluntary and involuntary control.
- It is a mechanical process consisting of two phases, inspiration & expiration.
- During rest, normal breathing rate is 15-20 breaths/min in humans and it can increase to 30/min during exercise.

Phases of Breathing

Feature	Inspiration	Expiration
Another name	Inhalation	Exhalation
Basic Mechanism	Passive expansion of lungs	Passive contraction of lungs
Nature	Active process involving muscle contraction	Passive process involving elastic recoil
Definition	Taking in of air into the lungs	Removal of air low in O_2 and high in CO_2 from lungs outside body
Diaphragm	Contracts Moves down Becomes less dome-like	Relaxes Moves up Become more dome-like
Rib muscles	Contract	Relax
Rib cage	Moves upward, forward & outward	Moves downward, inward & backward

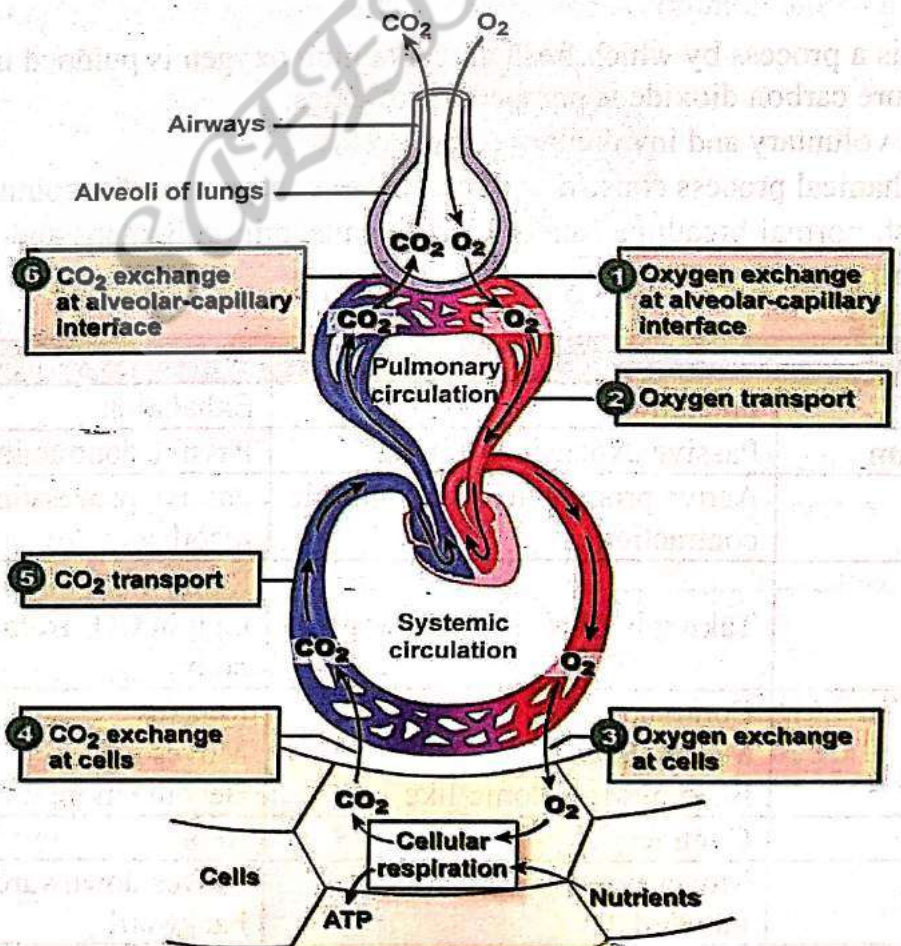
Overall Change in Volume	Increases	Decreases
Changes in Pressure	Decreases	Increases
Air moves	Into lungs	Out of lungs



(a) Inhalation *(b) Exhalation*

TRANSPORT OF GASES

- Gaseous exchange follows principles of diffusion.
- This exchange occurs due to difference in partial pressure of gases.



TRANSPORT OF OXYGEN

- Most of the oxygen is transported ***through haemoglobin.***
- A small proportion is transported through plasma in dissolved form.
- Haemoglobin acts as an efficient oxygen carrier.

At Lungs

- Haemoglobin readily combines with oxygen to form bright red oxyhaemoglobin.
- $Hb + O_2 \rightarrow HbO_2$
- ***Maximum capacity*** of haemoglobin to carry oxygen is about 20ml/100ml of blood at sea level. At this blood will be 100% saturated.
- Under normal conditions, blood of alveoli of lungs is not completely oxygenated.
- ***At 115 mmHg*** oxygen tension, there is 19.6ml of O_2/100ml of blood, where Hb is 98% saturated.

At Aerobic Tissue

- Oxyhaemoglobin is unstable and splits into the normal purple red haemoglobin and oxygen in the condition of low oxygen concentration and low pressure.
- Carbonic anhydrase enzyme present in RBC facilitates this activity.
- $HbO_2 \xrightarrow{\text{Carbonic Anhydrase}} Hb + O_2$
- ***Oxyhaemoglobin*** is unstable at pressure below 60 mmHg.
- Every 100ml of blood gives 5ml O_2 to aerobic tissue.

Factors Affecting O_2 Holding Capacity of Hb

1. Carbon Dioxide

- When carbon dioxide pressure increases, the oxygen tension decreases, the capacity to hold oxygen becomes less.
- Increased carbon dioxide tension favours the greater liberation of oxygen from the blood to the tissue.

2. Temperature

- Rise in temperature causes a decrease in oxygen carrying capacity of blood.
- For example, in increased muscular activity.

3. pH

- With decrease in pH of blood, amount of oxygen bound to haemoglobin also declines.
- Decreased pH results from increase in hydrogen ions. Hydrogen ions combine with the protein part of hemoglobin molecules causing a decrease in its ability to bind oxygen.

TRANSPORT OF CARBON DIOXIDE

- Carbon dioxide is more soluble than oxygen.
- CO_2 produced in Cell → Dissolved in Tissue Fluid → Passes to Plasma of Blood
- CO_2 is much more important than oxygen as a regulator of normal alveolar ventilation (breathing).

SOLED MDCAT

Ways of Transport of CO_2

20%	Carboxyhemoglobin/ Carbaminohaemoglobin
5%	Plasma Proteins
70%	Bicarbonate ions combined with sodium in plasma.
5%	Dissolved in Plasma
Small Amount	By corpuscles combined with potassium

- Carboxyhaemoglobin/Carbaminohaemoglobin is formed when carbon dioxide combines with amino group of haemoglobin.

Transport as Bicarbonate Ions

At Aerobic Tissue

- $CO_2 + H_2O \xrightarrow{\text{Carbonic Anhydrase}} H_2CO_3$
- $H_2CO_3 \rightarrow H^+ + HCO_3^-$

At Lungs

- $HCO_3^- + H^+ \rightarrow H_2CO_3$
- $H_2CO_3 \xrightarrow{\text{Carbonic Anhydrase}} CO_2 + H_2O$

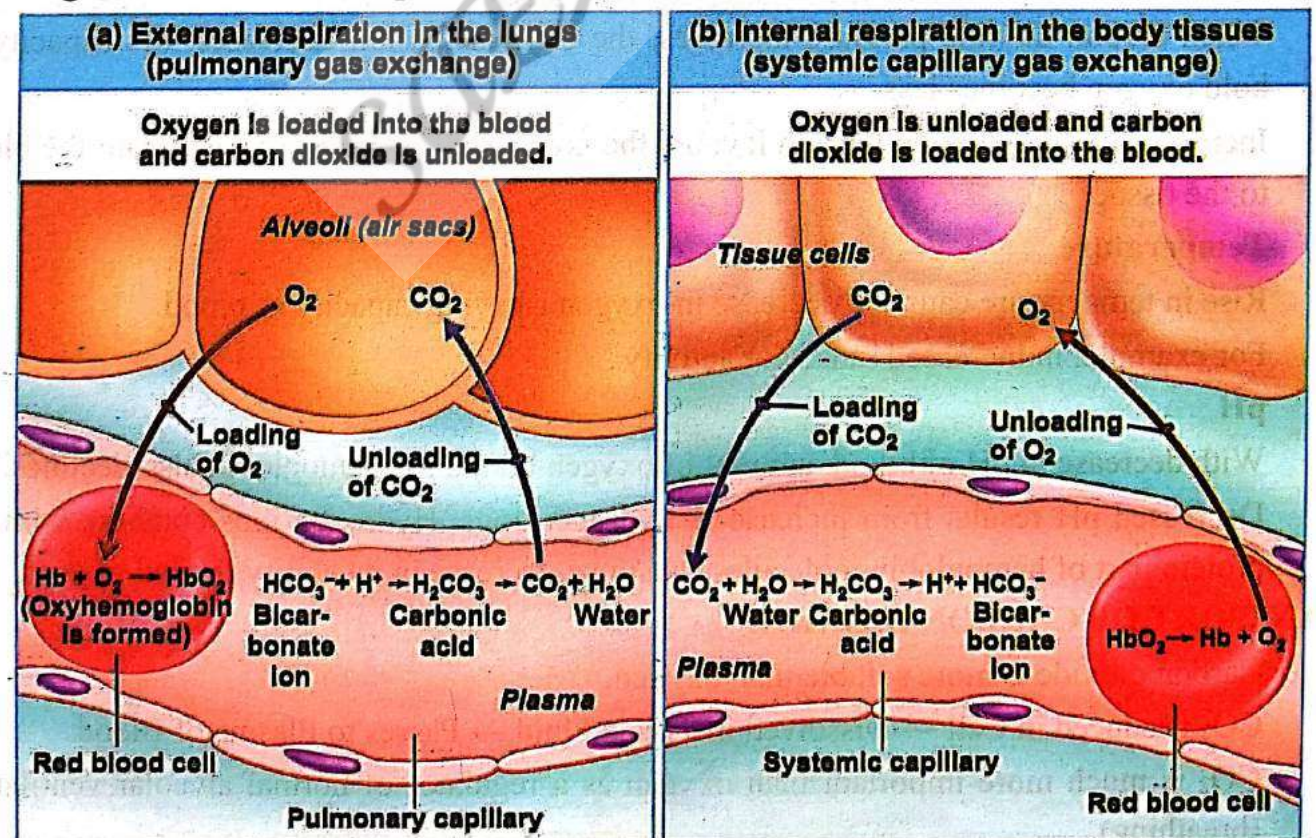
Capacity of Blood for CO_2

- ***Arterial blood*** contains about 50ml of CO_2/100ml of blood.
- ***Venous blood*** contains 54ml of CO_2/100ml of blood.
- Each 100ml of blood takes 4ml of carbon dioxide as it passes through the tissues and gives 4ml of CO_2 as it passes through lungs.

CRITICAL CONCEPT!

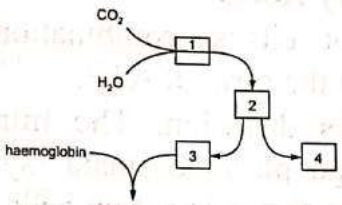
Hemoglobin as a Buffer

Hemoglobin is the principal protein inside of red blood cells and accounts for one-third of the mass of the cell. During the conversion of CO_2 into bicarbonate, hydrogen ions liberated in the reaction are buffered by hemoglobin, which is reduced by the dissociation of oxygen. This buffering helps maintain normal pH. The process is reversed in the pulmonary capillaries to re-form CO_2, which then can diffuse into the air sacs to be exhaled into the atmosphere.



CRITICAL THINKING

7. **The diagram shows the pathway for the transport of carbon dioxide that occurs in red blood cells.**



Which row is correct?

	1	2	3	4
A.	Carbaminohaemoglobin	Haemoglobinic acid	Hydrogen ions	Bicarbonate ions
B.	Carbonic anhydrase	Carbonic acid	Hydrogen ions	Bicarbonate ions
C.	Carboxyhemoglobin	Carbonic anhydrase	Carbonic acid	Carbon dioxide
D.	Haemoglobinic acid	Carbonic acid	Bicarbonate ions	Hydrogen ions

8. **Which of the following lung volumes would be different in a person at rest compared with when the person exercises?**
 A. Tidal volume B. Vital capacity
 C. Residual volume D. Total lung capacity
9. **Tidal volume in respiration is analogous to what measurement in cardiac physiology?**
 A. Cardiac output B. Heart rate
 C. Stroke volume D. Systolic pressure

TRANSPORT

UPTAKE AND TRANSPORT OF MINERALS AND WATER

- The roots of a plant not only anchor the plant body in the soil, but also absorb minerals and water from the soil.
- There are three types of nutrients needed by the plants, carbon dioxide, water and minerals besides light to carry out photosynthesis.
- To get these materials, roots must provide large surface area for absorption, which is achieved by extensive branching.
- The roots bear a dense cluster of tiny hair like structures which are extensions of epidermal cells of roots.
- These are the root hairs, which are in fact the sites where most of the uptake of water and minerals takes place.
- Plants are able to synthesize all their required compounds, with the help of the minerals and H_2O from soil, CO_2 from air, and light energy.
- Most of the minerals enter the root hairs or epidermal cells of roots along with water in bulk flow, but some are taken in by diffusion, facilitated diffusion, or active transport.

Mineral Absorption by Roots

The minerals available to plants for absorption are dissolved in the soil water.

- Their concentration varies according to the fertility and the acidity of the soil, besides other factors.
- When the soil minerals are not in solution but are, bound by ionic bonds to soil particles, they are not available to plants.

Processes Involved in Absorption by Roots

- The uptake of minerals by root cells is a combination of passive uptake and active uptake, involving the use of energy in the form of ATP.
- The passive uptake involves diffusion. The minerals they also move down their concentration gradient through plasmodesmata (symplast pathway) to cells of cortex, endodermis, pericycle and then to sap in xylem cells.
- From here they are pulled up by transpiration pull to different parts of plant,
- The ***diffusion*** of ions along with water also takes place by mass flow along the apoplast pathway. Ions moving in the apoplast can only reach the endodermis, where casparian strips prevent further progress.
- To cross the endodermis, ions must pass by diffusion or active transport into endodermis cells, entering their cytoplasm, and possibly their vacuoles. The ions then reach the xylem cells.
- Diffusion of ions can also take the vacuolar pathway where the ions move along their concentration gradient through the cell membranes, cytoplasm, and tonoplast (the membrane of vacuoles), and reach the dead xylem cells.
- Most of ions are taken up by the roots by the process of active transport.
- By this method plants can take a mineral that is in higher concentration inside the root cells than in the soil solution.
- In this process molecules and ions move from their low concentration to their higher concentration (i.e. against the concentration gradient), through cell membrane, by the use of energy in the form of ATP.
- Active transport is selective and is dependent on respiration. Some ions move by passive as well as by active transport.
- Some nutrients are carried from the soil to the epidermal cells of roots through their cell membrane by **facilitated diffusion**.
- In this type of diffusion, carrier molecules within the cell membrane transport nutrients across the membrane.
- These carrier molecules are proteins which are present within cell membrane of epidermal and other root cells.

UPTAKE OF WATER BY ROOTS

- There are three types of nutrients needed by plants, carbon dioxide, water and minerals besides light to carry out photosynthesis.
- ***Root hairs*** are dense cluster of tiny hair like structure which is ***extensions of epidermal cells of roots.***
- 67% of the total surface area of the roots is provided by the root hair.
- These are the sites where most of the uptake of water and minerals take place.
- When the soil minerals are not in the solution form rather bound by ionic bond to soil particles, they are not available to plants.
- The rate of absorption of individual mineral which is independent of rate of absorption of water molecules is determined by

(i) Concentration both inside and outside of the root cells.
(ii) The ease with which it can passively penetrate cell membrane.
(iii) Extent to which carrier molecules and active absorption is involved.

Processes Involved in Absorption by Roots

- Minerals with higher concentration in root cells can also be taken in (against the concentration gradient).
- It utilizes energy in the form of ATP.
- Such type of diffusion that occurs through carrier proteins is called facilitated diffusion.

Uptake of Water by Roots

- Movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane is called ***osmosis***.
- Movement of water molecules by osmosis into a cell is called ***endosmosis***.
- Movement of water molecules by osmosis outside a cell is called ***exosmosis***.
- Three pathways are commonly involved in transport of water and minerals i.e. ***apoplast, symplast*** and ***vacuolar pathway***.

Apoplast Pathway

- This involves system of adjacent cell walls which is continuous throughout the plant roots.
- In the roots, apoplast pathway becomes discontinuous in the endodermis due to the presence of ***casparian strips***.
- Apoplast pathway is of greatest importance for both water and solute transport.

Symplast Pathway

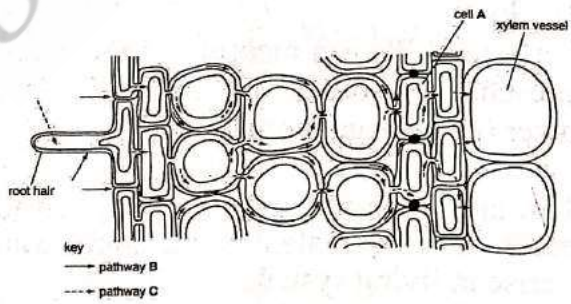
- Symplast pathway is the system of interconnected protoplasts in the root cells.
- Cytoplasms of neighboring cells (protoplast) are connected with one another by ***plasmodesmata*** (cytoplasmic strands that extend through pores in adjacent cell walls).

Vacuolar Pathway

- In this pathway, water move passively down the concentration gradient from vacuole to vacuole.

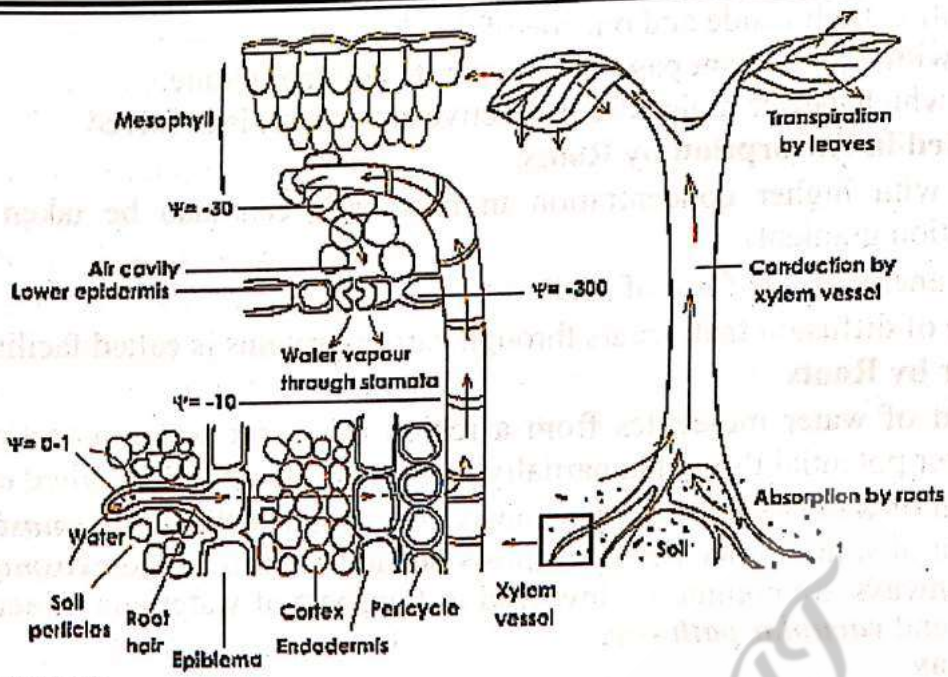
CRITICAL THINKING

10. Water absorbed by plant roots travels by different pathways from root hairs to the xylem. Figure shows these pathways in the root of *Ranunculus acris*.



Name Cell A and Pathway B:

	Cell Name	Pathway Name
A.	Endodermis	Apoplast
B.	Cortex	Symplast
C.	Pericycle	Vacuolar
D.	Endodermis	Symplast



WATER POTENTIAL

Water molecules possess kinetic energy which means that in liquid or gaseous form, they move about rapidly and randomly from one place to another. So, greater the concentration of the water molecules in a system the greater is the total kinetic energy of water molecules: This is called water potential (Ψw).

Factors effecting water potential:

In plant cells, two factors determine water potential.

- Solute concentration (Osmotic or solute potential = Ψs)
- Pressure generated when water enters and inflates plant cells (Pressure potential = Ψp).
- Pure water has maximum water potential which by definition is zero. Water moves from a region of higher Ψw to lower Ψw,
- All solutions have lower Ψw than pure water and so have negative value of Ψw (at atmospheric pressure and at a defined temperature).

Osmosis:

Osmosis can be defined as:

"The movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane".

Osmotic (Solute) Potential = Ψs

The osmotic (solute) potential Ψs is a measure of the change in water potential Ψw) of a system due to the presence of solute molecules. Ψ_S is always negative. More solute molecules present, lower (more negative) is the Ψs.

Pressure Potential (Ψs)

- If pressure greater than atmospheric pressure is applied to pure water or a solution, its water potential increases. It is equivalent to pumping water from one place to another. Such a situation may arise in living systems.
- When water enters plant cells by osmosis pressure may be built up inside the cell making the cell turgid and increasing the pressure potential. Thus the total water potential is sum of Ψs and Ψp.

Ψw	=	Ψs	+	Ψp
Water potential		**solute potential**		**Pressure potential**

- If we use the term water potential, the tendency for water to move between any two systems can be measured; not just from cell to cell in a plant but also from soil to root from leaf to air or from soil to air. The steeper the potential gradient the faster is the flow

The following example would help understand the concept of water potential. Two adjacent vacuolated cells are shown with Ψw, Ψp and Ψs.

ASCENT OF SAP

CRITICAL THINKING

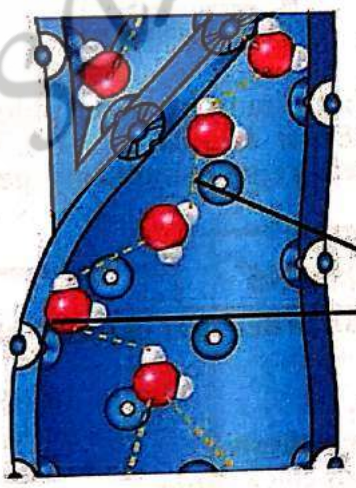
11. All of the following have an effect on water potential (Ψ) in plants except:

A. Physical pressure
B. Organic solutes
C. Inorganic solutes
D. DNA

- Pulling upward of water and dissolved minerals towards the leaves through the xylem tissue is called ascent of sap.
- It is explained through ***cohesion tension theory***, ***root pressure*** and ***imbibition***.

Cohesion Tension Theory

- It was proposed by Dixon.
- According to this theory, uptake of water ***depends upon cohesion and tension***.
- ***Cohesion*** is the attraction among water molecule (H-bond) forming a solid chain like column within the xylem tubes.
- ***Tension*** is provided when water chain is pulled up in the xylem. ***Transpiration*** provides the necessary energy or force. This xylem tension is strong enough to pull water up to **200 meters in plants**.
- ***Adhesion*** develops between water molecules and cell wall of xylem cells. The composition of cell wall provides necessary adhesion to water molecules that helps water creep up. The ***cellulosic component*** of cell wall especially has great affinity for water.
- It is essential that the xylem walls should have high ***tensile strength***. The lignin and cellulose provides strength to cell wall of xylem vessels.
- Large quantities of water are carried at relatively high speed, ***upto 8m/h*** being recorded in tall trees, and commonly in ***other plants at 1m/h***.
- The total water pulled up in the leaves is transpired, except about 1% which is used by plants in various activities including photosynthesis.



Cohesion and adhesion create tension within xylem that helps move water upward.

Root Pressure

- A pressure created by active secretion of salts and other solutes from root cells into xylem sap, which lowers the water potential of the xylem sap is called root pressure.
- A pressure of 100 – 200 KPa (exceptionally 800 KPa) is generated by root pressure.
- ***Guttation or exudation*** is a loss of liquid water through ***water secreting glands or hydathodes***.
- It is caused by root pressure in small plants like grasses. It is more notable when transpiration is suppressed, and the relative humidity is high at night.

Imbibition

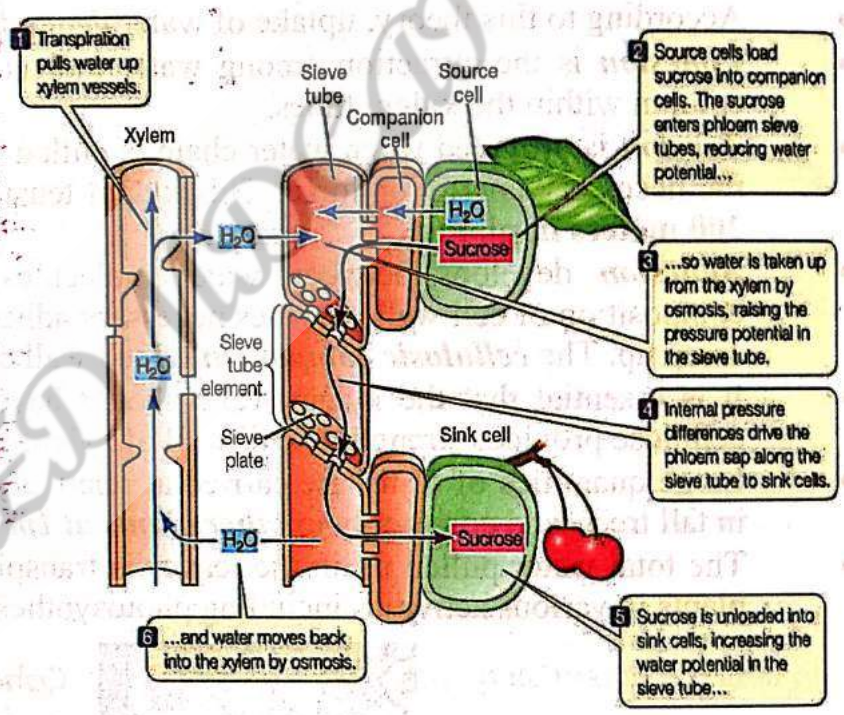
- It was first proposed by Sacks.
- The cell walls components especially ***cellulose, pectin and lignin*** can take up water and as a result increase in volume, but the components do not dissolve in water, this is called imbibition.
- The root cell walls imbibe water from the soil, and this water moves by apoplast pathway.
- It is a ***reversible process***.

Bleeding

- Flow of sap from cut ends or surfaces is called bleeding.
- It is mostly seen in land plants in spring.
- Although the flow of sap is ordinarily slow, a considerable quantity of the sap within a period of 24 hours comes out of the plant, e.g. in some palms when tapped, there may be a flow of sap to the extent of ***10-15 L/day***.
- It is created by two factors i.e. ***hydrostatic pressure and root pressure***.

TRANSLOCATION OF ORGANIC SOLUTES

- The phloem constitutes the ***inner bark***.
- The cells of phloem that conduct or transport sugars and organic material throughout the plant are called sieve elements.
- Transport or translocation occurs from the area of supply (sources) to area of metabolism or storage called sinks.
- In biennials e.g. root of beet is a sink in first growing season but becomes source in the next growing season, when sugars are utilized in growth of new shoots.
- The movement in phloem is from source to sink in most of the plant during active photosynthesis.



Pressure Flow Theory

- The theory called ***pressure flow theory*** is the most acceptable theory for the transport in the phloem of angiosperms.
- A hypothesis was first proposed by ***Ernst Munch*** in 1930. It states that the flow of solution in the sieve elements is driven by an osmotically generated pressure gradient between source and sink.

CRITICAL THINKING

12. Arrange the following five events in an order that explains the mass flow of materials in the phloem.

1. Water diffuses into the sieve tubes.
2. Leaf cells produce sugar by photosynthesis.
3. Solutes are actively transported into sieve tubes.
4. Sugar is transported from cell to cell in the leaf.
5. Sugar moves down the stem.

A. 2, 1, 4, 3, 5
B. 1, 2, 3, 4, 5
C. 2, 4, 3, 1, 5
D. 4, 2, 1, 3, 5

CARDIOVASCULAR SYSTEM

STRUCTURE OF HUMAN HEART

Introduction

- The human heart is ***located in the chest cavity*** between lungs slightly left of the sternum.
- The heart contracts automatically with rhythmicity, under the ***control of the autonomic nervous system***.
- Human heart is hollow, fibromuscular organ. Adult heart has shape of cone.
- Base of heart extends to ***second*** intercostal space and apex of heart is in ***fifth*** intercostal space, approximately ***9 cm to left of midline***.

Pericardium

- It is a closed sac that surrounds heart. Consists of 2 parts; outer and inner part.
- Outer part is inelastic white fibrous tissue. Inner part is made up of 2 membranes.
- Inner membrane is attached to heart and outer one is attached to fibrous tissue.
- ***Pericardial fluid*** is secreted between them and ***reduces friction*** between heart wall and surrounding tissues when heart is beating. Inelastic nature of pericardium as whole prevents heart from being ***overstretched*** or overfilled with blood.

Heart Walls

- The wall of the heart is composed of three layers: Epicardium, Myocardium and Endocardium.
- ***Epicardium*** is a thin serous membrane comprising of smooth outer surface of heart
- ***Myocardium*** of heart is made up of special type of muscles, the cardiac muscles. Their arrangement and mechanism of contraction is essentially same as skeletal muscles except that they are branched cells. Successive cells are separated by junctions called ***intercalated discs***.
- Endocardium consists of simple squamous epithelium over a layer of connective tissue. Heart valves are formed by fold of endocardium.

Heart Chambers

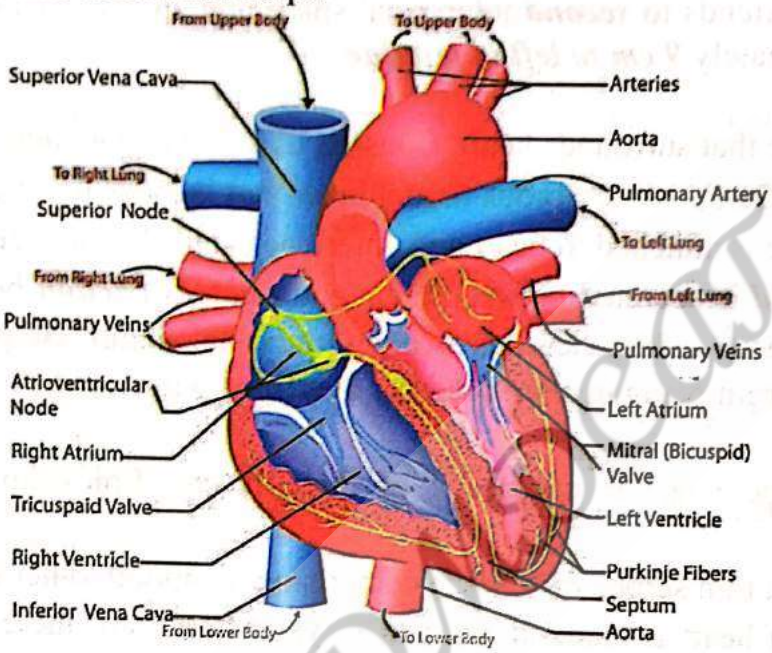
- There are 2 atria and 2 ventricles found in the human heart. They are separated from each other by ***atrioventricular groove*** or ***sulcus***.
- Interatrial groove separates atria and interventricular groove separates ventricles. In normal intact heart the sulci are covered by fat.
- ***Atrioventricular valve*** is on each atrioventricular canal and is composed of cusps or flaps.
- ***Tricuspid*** valve has 3 flaps and is present between right atrium and ventricle. ***Bicuspid*** valve (Mitral) has 2 flaps and is present between left atrium

CRITICAL CONCEPT!

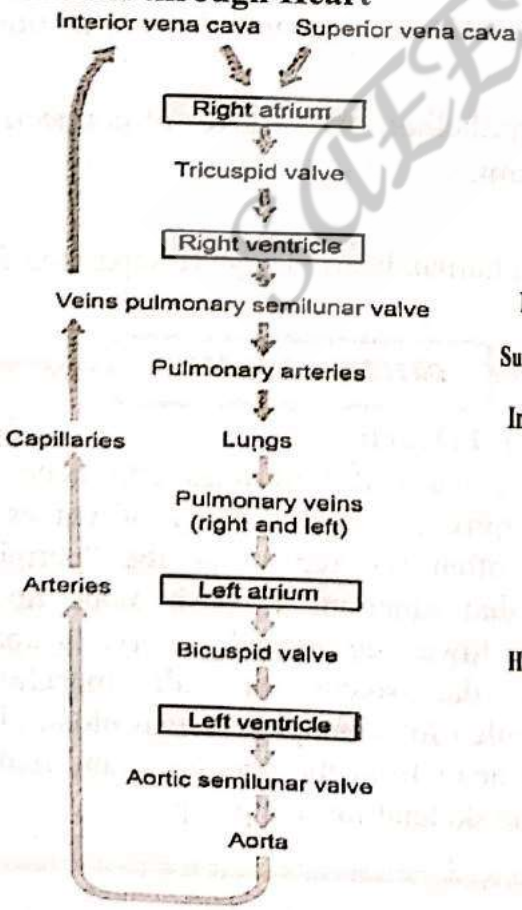
Peripheral Heart:
Together, the calf's muscles and deep vein system form a complex array of valves and pumps, often referred to as the "peripheral heart," that functions to push blood upward from the lower leg against gravity. In upright posture, the soleus (a calf muscle) is responsible for pumping *venous* blood back into the heart from the periphery, and is often called the skeletal-muscle pump.

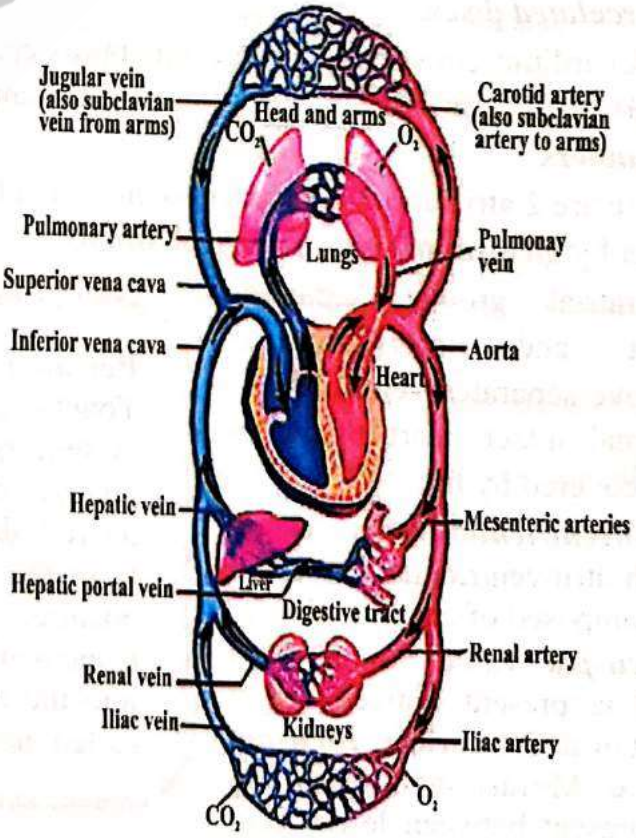
SCIENCEMDCAT

- Complete separation of deoxygenated and oxygenated blood is maintained by formation of ***septa***.
- Each ventricle contains cone shaped muscular pillars called ***papillary muscles*** that are attached by thin, strong connective tissue strings called ***chordae tendineae*** to cusps of atrioventricular valves.
- Aorta and pulmonary trunks have aortic and pulmonary valves. Each valve consists of 3 pockets, free inner borders of which meet in center of artery to block blood flow.
- ***Semilunar valves*** are present at base of aorta and pulmonary trunk. Each valve consists of three pockets like semilunar cusps.



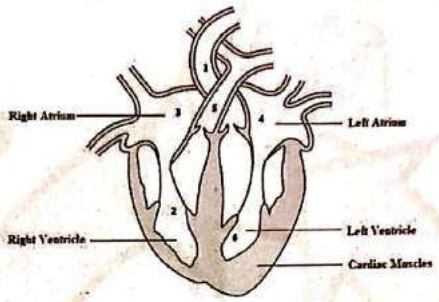
Blood Circulation through Heart





CRITICAL THINKING

13. Trace down flow of blood in heart:

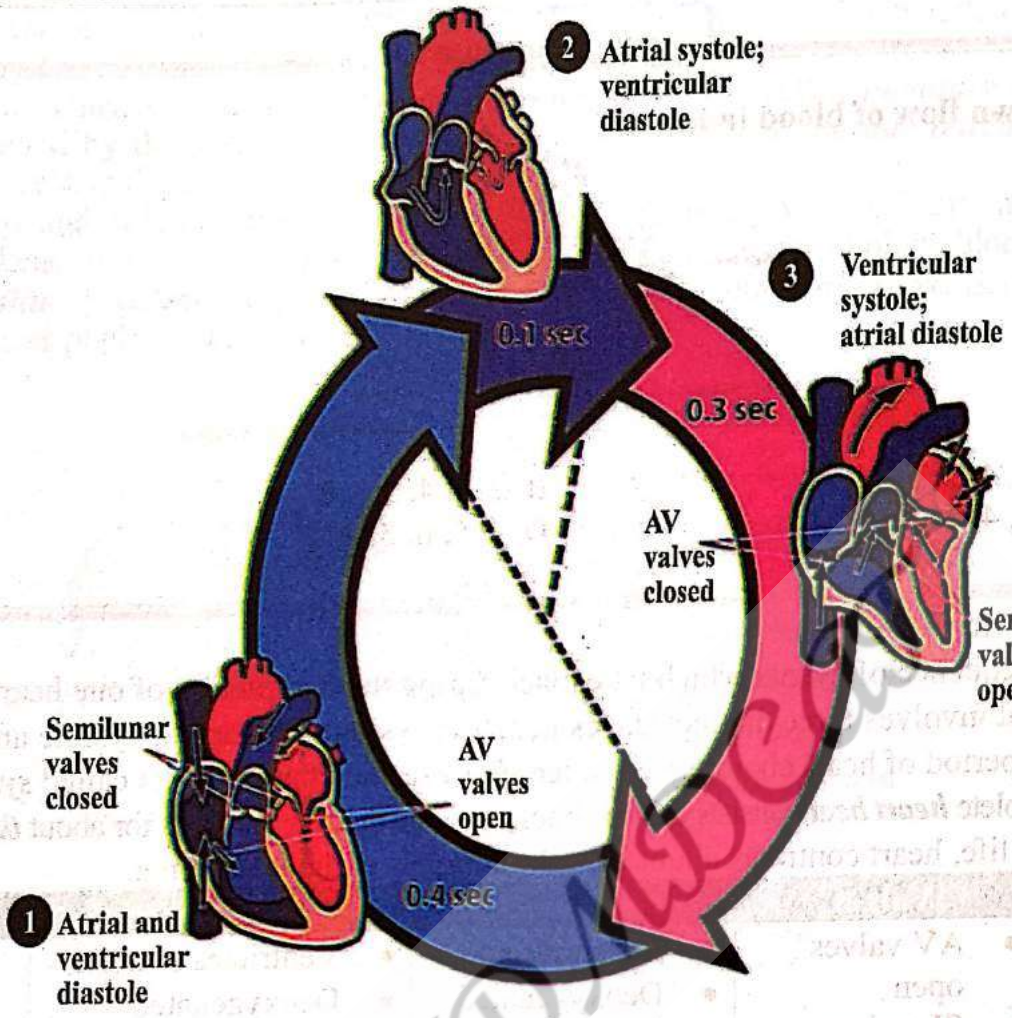


A. 1, 2, 3, 4, 5, 6
B. 2, 3, 4, 5 1, 6
C. 3, 2, 5, 4, 6, 1
D. 4, 5, 6, 3, 2, 1

The Cardiac Cycle

- It is the sequence of events which take place during the completion of one heartbeat.
- Heart beat involves three distinct stages i.e. atrial systole, ventricular systole and diastole.
- Relaxed period of heart chambers is called ***diastole*** and contraction is called ***systole***.
- One complete ***heart beat*** consists of one systole and one diastole and lasts for about ***0.8 seconds***.
- In one's life, heart contracts about 2.5 billion times, without stopping.

Phase	Valves	Events in Atria	Events in Ventricles	Duration
Diastole (Relaxation)	• AV valves open • SL valves closed	• Atria relaxed • Deoxygenated blood enters right atrium by vena cava • Oxygenated blood enters left atrium by pulmonary veins	• Ventricles relaxed • Deoxygenated blood enters right ventricle through right atrium • Oxygenated blood enters left ventricle through left atrium.	0.4 sec
Atrial Systole	• AV valves open • SL valves closed	Muscles of atria contract and pump blood to ventricles	Ventricles are relaxed and receive blood from atria.	0.1 sec
Ventricular systole	• AV valves close (LUBB sound) • SL valves open at the beginning • SL valves close at the end of systole (DUBB sound)	Atria are relaxed during this phase	• Both ventricles contract • Left ventricle pumps oxygenated blood via aorta to all parts of body • Right ventricle pumps deoxygenated blood to lungs via pulmonary arteries	0.3 sec approx.



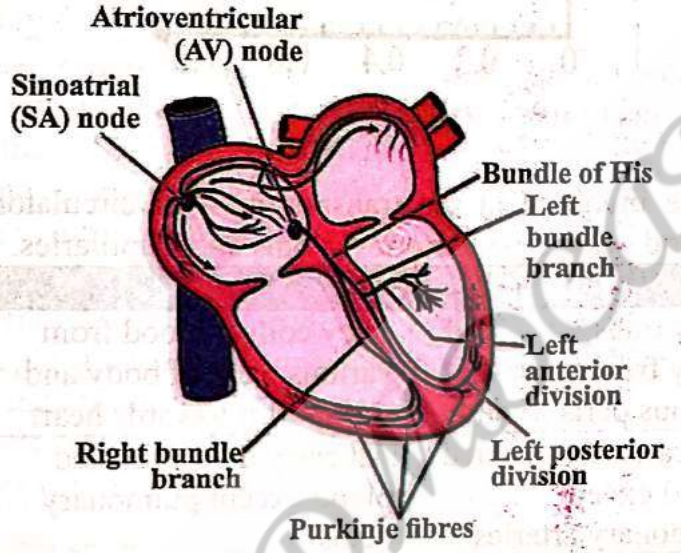
Mechanism of Heart Excitation and Contraction

- Specialized strands of interconnecting cardiac muscle tissue that coordinate cardiac contraction constitute the ***conduction system***. The conduction system constitutes the cardiac cycle. Cardiac muscle has an ***intrinsic rhythmicity***
- Heartbeat starts when the sino-atrial node (***pacemaker***) sends out electrical impulses to the atrial muscles, thus causing both atria to contract. It is located at the upper end of right atrium.

Components	Structure
Sinoatrial Node	It consists of **i)** Diffusely oriented cardiac fibers **ii)** Few myofibrils **iii)** Few nerve endings from autonomic nervous system in the upper wall of the right atrium. It is close to where vena cava enter the atrium. SA node is developed from the ***sinus venosus*** and has become a part of the atrium, so it is called sinoatrial node
Atrioventricular Node	Another specialized group of cardiac muscle fibers called ***atrio-ventricular node***. AV node is present near the junction of right atrium and right ventricle
Atrioventricular Bundle	AV node is connected to a strand of specialized muscles (in the ventricular septum) known as atrioventricular bundle or bundle of His. This bundle passes through a small opening in the fibrous skeleton to reach the interventricular septum, where it, divides to form right and left bundle branches which extend beneath the ***endocardium*** on either side of the interventricular septum to the apices of the right and left ventricles

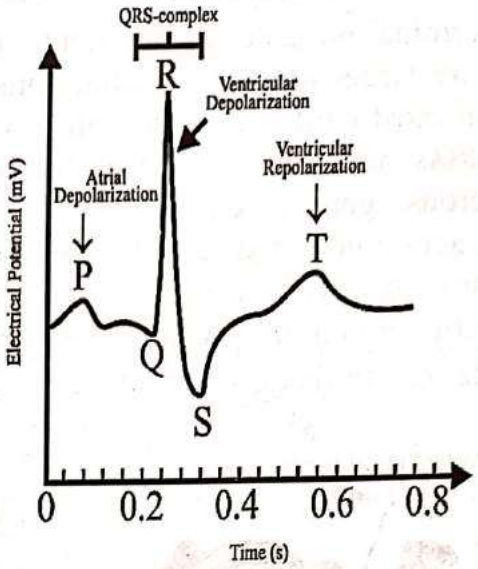
Conducting Myofibrils	The inferior, terminal branches of the bundle branches are called ***Purkinje fibres***, which are large- diameter cardiac muscle fibres. They have fewer ***myofibrils*** than most cardiac muscle cells and do not contract forcefully. ***Intercalated disks*** are well developed between the Purkinje fibres and contain numerous gap junctions. As a result of these structural modifications, action potentials travel along the Purkinje fibres much more rapid than through other cardiac muscle tissue. SA node generates spontaneous action potentials greater frequency.

- (0.04 seconds for nerve potential to reach AV node & 0.15 sec delay from AV node to AV bundles



Electrocardiogram

Introduction	The electrical impulses that pass through the conduction system of the heart during cardiac cycle
Electrocardiograph	The electrical changes from depolarization and repolarization of cardiac muscle fibres and can be detected on surface of the skin using an instrument called the ***electrocardiograph***
P Wave	***Depolarization*** of the atrial fibres of the SA node produces the P wave. The ventricles of the heart are in diastole during the expression of the P wave
P-R Interval	On the ECG recording, the P-R interval is the period of time from the start of the P wave to the beginning of the QRS complex. This interval indicates the amount of time required for the SA depolarization to reach the ventricles
QRS Complex	The QRS complex begins as a short downward deflection (Q), continues as a sharp upward spike (R), and ends as a downward deflection (S). The QRS complex indicates the ***depolarization*** of the ventricles
S-T Segment	During this interval, the ventricles are in ***systole*** and blood is being ejected from the heart. The time duration known as the S-T segment represents the period between the completion of ventricular depolarization and initiation of ***repolarization***
T Wave	The T wave is produced by ventricular ***repolarization***



BLOOD VESSELS

- Blood vessels are involved in the transportation of circulatory fluid(blood). They are three types of blood vessels i.e. Arteries, Veins and Capillaries.

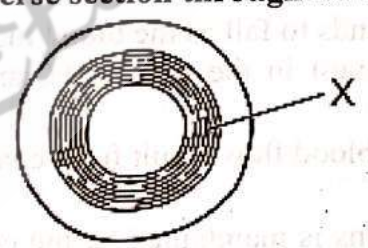
Feature	Arteries	Veins	Capillaries
Direction of Blood Flow	They transport blood away from heart to various parts of body	They collect blood from various parts of body and transport it towards heart	They link arteries with veins
Type of Blood	All carry oxygenated blood except pulmonary arteries	All carry deoxygenated blood except pulmonary veins	They have mixed blood
Structure	• Three layers • ***Tunica Adventitia***: Connective tissue + Elastic fibers • ***Tunica Media***: Circular smooth muscles + Elastic fibers • ***Tunica Intima***: simple squamous epithelium and elastic fibers composed of elastin	• Three layers • ***Tunica Adventitia***: Collagenous Connective Tissue • ***Tunica Media***: Circular smooth muscles + Thin elastic membrane + Collagen fibers • ***Tunica Intima***: Endothelium + Elastic fibers + Smooth Muscle	Only one cell thick endothelium
Elasticity	Elastic	Less elastic	Inelastic
Pulsatile Nature	Pulsatile	Non-pulsatile	Non-pulsatile
Valves	No valves except at the base of aorta& pulmonary trunk	Semilunar Valves are present to prevent the backflow of blood	No valves
Blood Pressure	High blood pressure	Low blood pressure	Falling pressure in these

Rate of Blood Flow	Rapid blood flow 400-500 mm/sec	Increases from smaller to larger veins	Blood flow is slowest 1mm/sec
Exchange of Material	No exchange of materials	No exchange of materials	Exchange of materials
Bore and Thickness	Have smaller bore and thick walls	Have larger bore and thin walls	Larger bore; wall one cell in thickness

Some Other Features	
Arteries	Contraction of ***circular smooth muscles*** of arteries and arterioles is under control of the nervous system and endocrine system. When stimulated the muscles contract, constricting the arterioles (vasoconstriction) and thus ***reducing*** the flow of blood in them and vice versa
Veins	In veins, muscle contraction also assists (squash blood vessels) in blood flow return towards heart along with valves. ***Portal veins*** carry blood to any organ other than the heart. For example, hepatic portal vein carries blood from intestine to liver
Capillaries	In liver, every cell is in direct contact with capillary. The diameter of a capillary can be altered by nervous stimulation, which tends to close them and by chemicals, such as ***histamine***, which dilate them. The change in diameter is brought about by change in shape of cells. The ***pre-capillary sphincters*** also regulate the amount of blood flowing in capillaries. Exchange of materials between blood and cells occurs through with extracellular fluid. It involves diffusion, active transport and endocytosis

CRITICAL THINKING

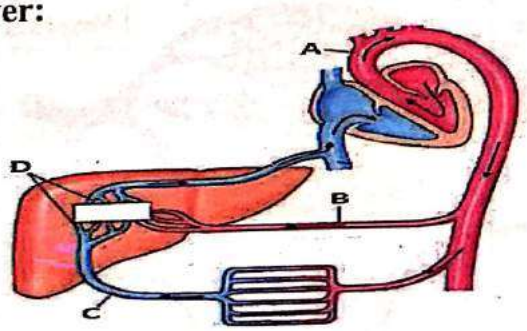
14. The diagram shows a transverse section through an artery:



Which statement describes the tissues present in layer X?

A. Collagen and smooth muscle only
B. Elastic fibres and collagen only
C. Elastic fibres and smooth muscle only
D. Elastic fibres, collagen and smooth muscle

15. Select an option of blood vessel which carry diffusible food particles from small intestine to liver:



SAEED MOGHAL

BLOOD PRESSURE AND RATE OF BLOOD FLOW

Blood Pressure

- "It is the measure of force with which blood pushes up per unit area against the walls of blood vessels".
- It is measured in mmHg.
- Blood pressure is detected by mechanoreceptors called ***baroreceptors***.
- It is the force that keeps blood flowing from the heart to all the capillary networks in the body.
- The blood pressure is generated by the contraction of ventricles. This is called ***systolic pressure***.
- When the ventricles relax, the atrial pressure is lowest and is called ***diastolic pressure***.
- Blood pressure consistently decreases in the following pathway:
 Aorta → Arteries → Capillaries →Veins → Vena cava
- The normal systolic blood pressure is ***120 mm Hg*** which is during ventricular systole.
- The normal diastolic blood pressure is ***75-85 mm Hg*** which is during diastole of the heart.

CRITICAL THINKING

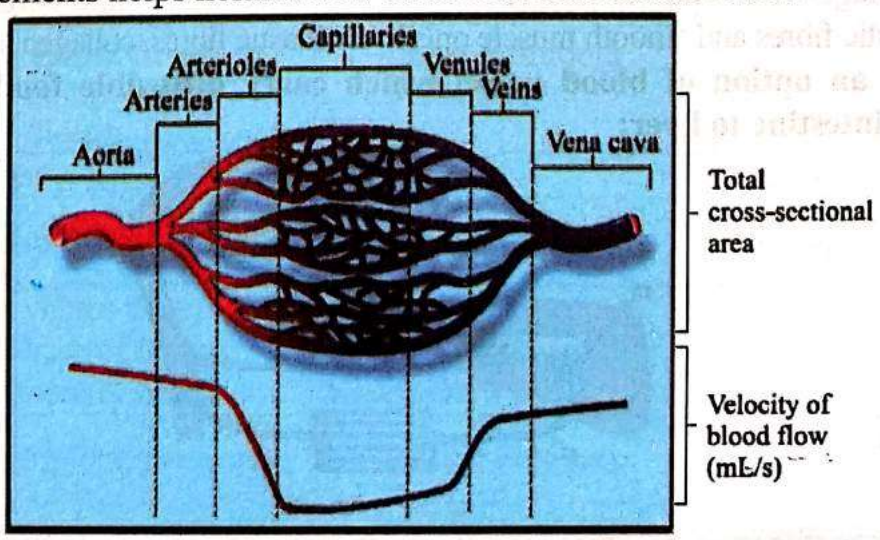
16. Which of the following is correct for a blood pressure reading of 130/80?

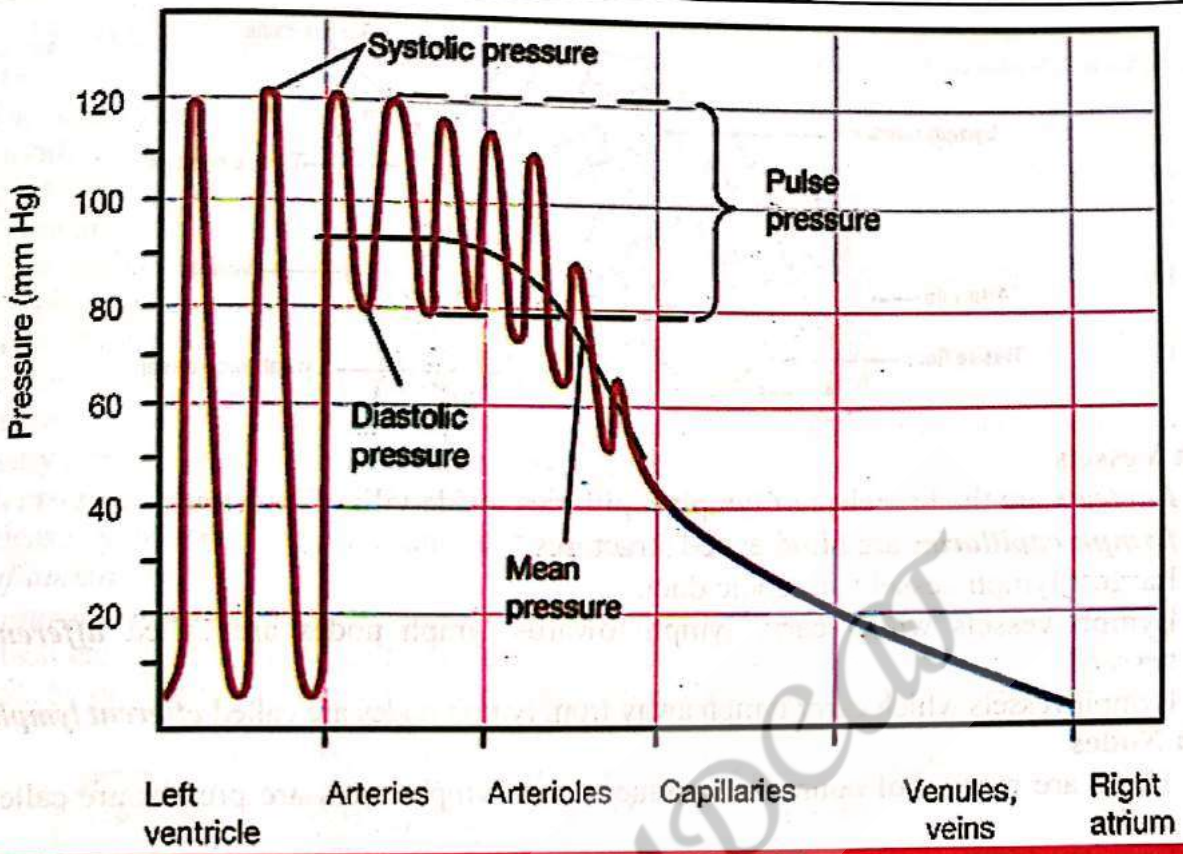
(i) The systolic pressure is 130.
(ii) The diastolic pressure is 80.
(iii) The blood pressure during heart contraction is 80.

A. I only
B. III only
C. I and II only
D. II and III only

Rate of Blood Flow

- The rate of blood flow tends to fall as the blood moves through the branching arteries and arterioles, the rate is lowest in the capillaries; and increases again in the venules and veins.
- These charges in rate of blood flow result from changes in the total cross sectional area of the vessel system.
- The flow of blood in veins is maintained by the contraction of surrounding muscles, the action of semilunar valves which prevent back flow of blood, Muscular activity including breathing movements helps normal flow of blood in the blood vessel.





LYMPHATIC SYSTEM

Introduction

- This system is responsible for the ***transport and returning of material*** from the tissues of the body to the blood.
- It comprises of lymph capillaries, lymph vessels, lymphoid masses, lymph nodes, and lymph.

Components of Lymphatic System

Lymph

- ***Lymph*** is the fluid which flows in the system.
- The ***lymph vessels*** empty in veins; so lymph is a fluid in transit between interstitial fluid and the blood.
- The ***intercellular spaces*** in the walls of lymph vessels are larger than those of the capillaries of blood vascular system.
- In an average person, about three liters more fluid leaves the blood capillaries that are re-absorbed by them each day.
- After a fatty meal, the fat globules may make up 1% of the lymph.

CRITICAL THINKING

17. Which row correctly identifies the locations in which a type of molecule or cell can be present?

	Type of Molecule or Cell	Blood	Lymph	Tissue Fluid
A.	Antigens	✓	×	×
B.	Glucose	✓	×	✓
C.	Lymphocyte	×	✓	✓
D.	Neutrophils	✓	✓	✓



Lymph Vessels

- ***Lacteals*** are the branches of lymph capillaries inside villi of intestine.
- ***Lymph capillaries*** are blind ended structures.
- Largest lymph vessel is thoracic duct.
- Lymph vessels which carry lymph towards lymph nodes are called ***afferent lymph vessels.***
- Lymph vessels which carry lymph away from lymph nodes are called ***efferent lymph vessels.***

Lymph Nodes

- These are masses of connective tissue where lymphocytes are present are called ***lymph nodes.***
- Lymph nodes are present in neck region, axilla and groin of humans.
- Several afferent lymph vessels enter a lymph node, which is drained by single efferent lymph vessel.
- Lymph nodes act as filter for lymph as do spleen for blood.

Flow of Lymph

- Direction of flow of lymph is:
 Lymph Capillaries → Smaller Lymph Vessels → Larger Lymph Vessels → Thoracic Duct → Subclavian Vein
- The flow of lymph is maintained by:

(i) Activity of skeletal muscles
(ii) Movement of viscera
(iii) Breathing movements
(iv) Semilunar valves that prevent backward flow

CRITICAL CONCEPT!

Location of lymphatic system:
Lymphatic system is responsible for returning of material that leaves the blood capillaries. Although it is absent in few body parts i.e. CNS, cornea and bones.

Functions of Lymphatic System

- Return of excess extracellular fluid and proteins to the blood.
- Absorption of large fat globules by lacteals of villi.
- Play important role in the defense system of the body. Lymphocytes and macrophages present inside lymph nodes kill bacteria and viruses.

CRITICAL THINKING?

18. The role of lymph in CNS is played by:

A. Tissue fluid
B. CSF
C. Blood plasma
D. Serum

SCEED MDCAT

IMMUNE SYSTEM

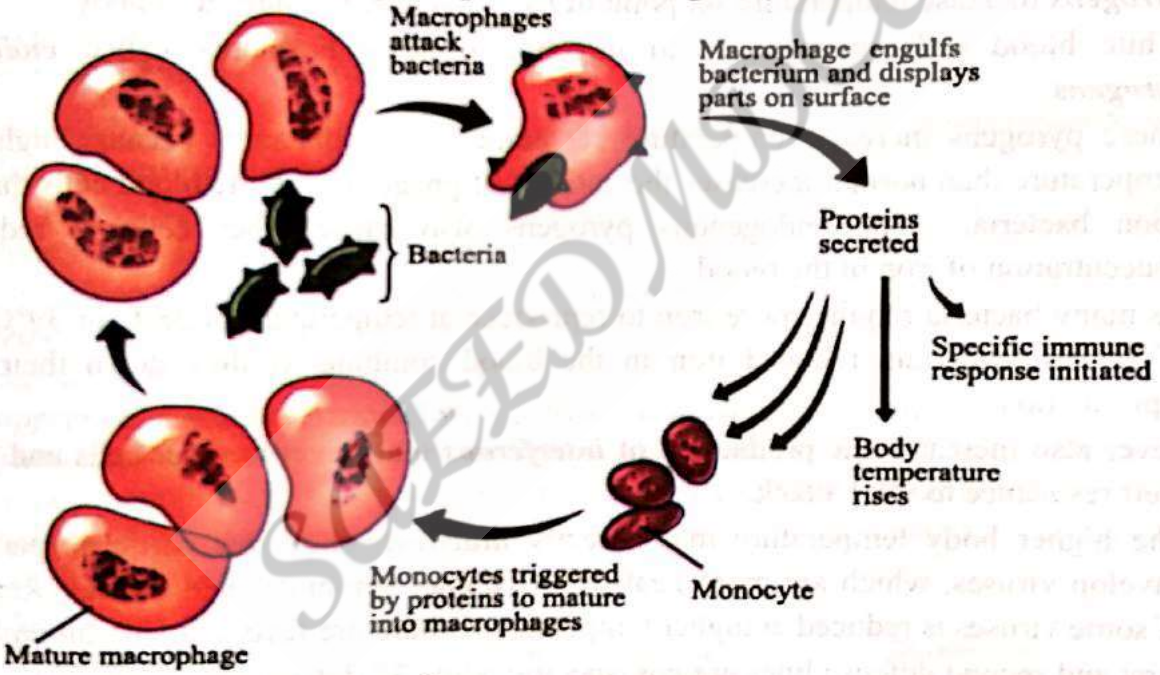
Immunity

- The capacity to recognize the intrusion of any material foreign to the body and to mobilize cells and cell products to help remove the particular sort of foreign material with greater speed and effectiveness is called ***immunity***.
- There are three defense lines of our body:

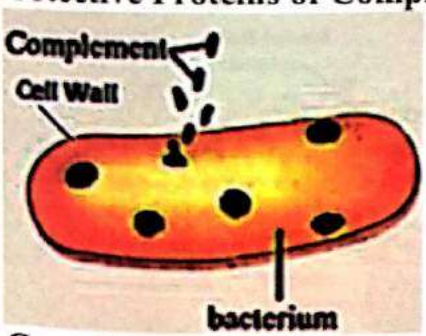
(i) ***First defense line*** is provided by physical and chemical barriers (Skin, Digestive and Respiratory Tracts).

(ii) ***Second defense line*** includes response by phagocytes, natural killer cells, inflammatory response and Fever.

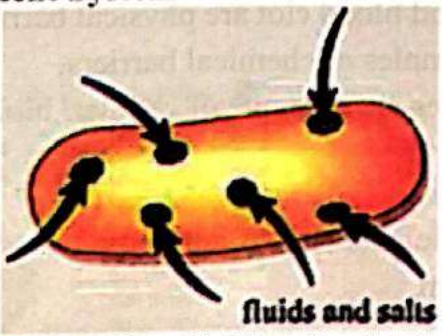
- ***Macrophages*** not only destroy pathogens and also act as antigen presenting cells. It produces many proteins. One of them is ***Interleukin-I*** that triggers brain to produce fever.
- ***Neutrophils*** are short lived. They are highly mobile and move like amoeba. Neutrophils also release ***lysosomal*** enzymes and certain chemicals that kill microorganisms and cause ***inflammation.***
- ***Natural killer cells*** are a type of T-cell. These cells do not attack microbes directly; rather attach cancerous cells or cells invaded by viruses. Produce holes in membranes of infected cells by ***perforins***. Then apoptotic proteases called ***granzymes*** enter into target cells.



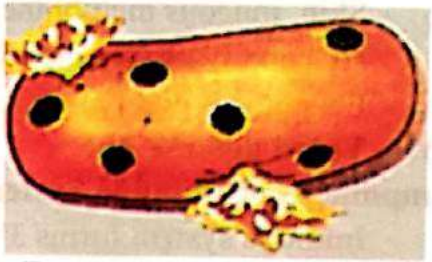
Protective Proteins of Complement System



Complement proteins holes in the bacterial cell wall and membrane



Holes allow fluid and salts to enter the bacterium



Bacterium expands until it bursts

Interferons

- Interferons (IFNs) belong to the large class of proteins known as cytokines, molecules used for communication between cells during infection.
- Interferons activate molecules which prevent the virus from producing and replicating its RNA or DNA.
- Interferons limit cell-to-cell spread of viruses in the body. IFNs also activate immune cells, such as natural killer cells and macrophages that in turn destroy virally infected cells.

Inflammatory Response

(1) Tissue injury; release of chemical signals such as histamine.	(2) Dilation and increased leakiness of local blood vessels; migration of phagocytes to the area.	(3) Phagocytes (macrophages and neutrophils) consume bacteria and cell debris; tissue heals.

Fever

- Fever or ***pyrexia*** is due to pyrogens that are chemicals released by invading organisms. ***Pyrogens*** increase temperature set point of hypothalamic thermostat of body.
- White blood cells in response to infection produce hormones called ***endogenous pyrogens***.
- These pyrogens increase temperature set point of hypothalamus because higher body temperature than normal increases the activity of phagocytic white blood cells that attack upon bacteria. The endogenous pyrogens also cause other cells to reduce the concentration of iron in the blood.
- As many bacteria require more iron to reproduce at temperature of 38°C or 39°C than at 37°C. So fever and reduced iron in the blood combine to slow down their rate of reproduction.
- Fever also increases the production of ***interferons*** that travel to other cells and increase their resistance to viral attack.
- The higher body temperature may directly ***inactivate*** the virus particles, particularly envelop viruses, which are more heat-sensitive than non-enveloped viruses. Replication of some viruses is reduced at higher temperatures, therefore fever may inhibit replication.
- First and second defense lines are non-specific while 3rd defense line is specific.
- Skin, mucous membrane and blood clot are physical barriers.
- HCl and lysozyme are examples of chemical barriers.
- Phagocytes and lymphocytes are example of cellular/ biological barriers.

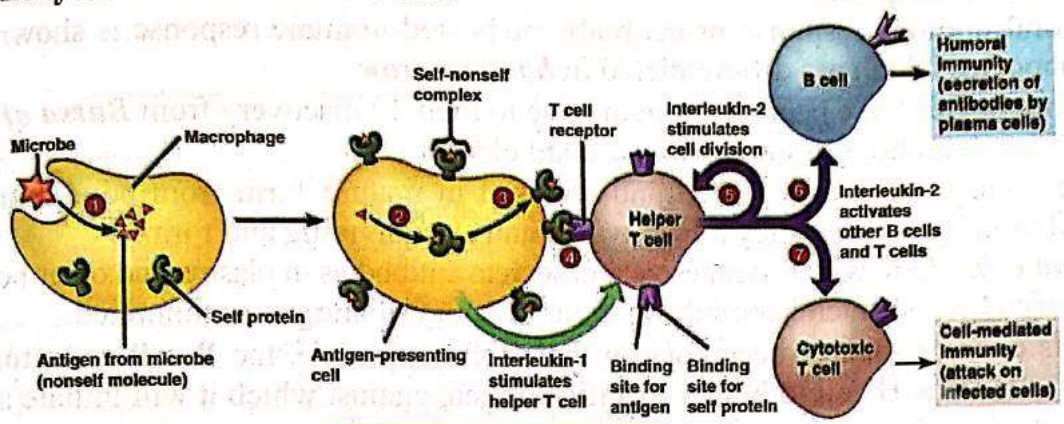
(iii) Third defense line

Components of Immune System

- Immune system forms 3rd defense line of our body.
- It is derived from mesoderm.
- It has two main components i.e. lymphocytes and antibodies.
- ***Antigen*** or ***immunogen*** is a foreign substance, often a protein which stimulates the formation of antibodies.
- It includes cell mediated (T cells) and humoral immune (B cells) responses.

SUEED MUDDASIR

Role of Monocytes in Third Line Defense



CRITICAL THINKING

19. Both lysozyme and cytotoxic T cells

A. Kill cells through chemical interactions
B. Kill cells by inducing apoptosis
C. Kill cells by generating a membrane attack complex
D. Are part of innate immunity

Cell Mediated Immune Response

- It is due to ***T-lymphocytes***. T cells are produced in bone marrow but they get matured in Thymus gland.
- T-lymphocytes are further divided into following categories:

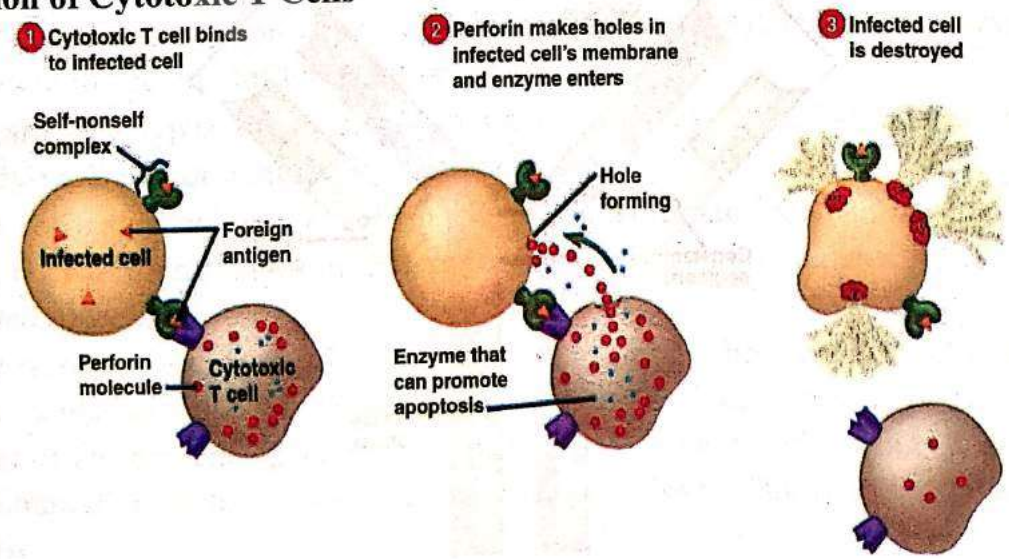
(i) ***Helper T-lymphocytes*** **(CD4)** recognize the antigen and inform other cells by releasing specific chemical substances (cytokines).

(ii) ***Suppressor T-lymphocytes*** **(CD8)** are involved in controlling immune response.

(iii) ***Cytotoxic T-lymphocytes*** **(CD8)** are involved in direct killing or destroying of antigens. For destruction, they usually depend upon lysosomes and peroxisomes.

(iv) ***Memory T-lymphocytes*** keep information/ memory of the antigen to protect body for next attack by same antigen.

Mode of Action of Cytotoxic T Cells



Humoral Immune Response

- Humoral immune response or antibody medicated immune response is shown by the B-lymphocytes which are differentiated in ***bone marrow***.
- B-lymphocytes have been given name due to their 1st discovery from ***Bursa of Fabricius***, which is a lymphoid tissue in birds around cloaca.
- In humans, these are produced and released in mature form from bone marrow. After stimulation by antigen, they are activated and start dividing and form:

(i) ***Plasma cells clone*** which synthesize and secrete antibodies in plasma and other body fluids.

(ii) ***Memory B-cells*** which keep information/ memory of antigen encountered.

- B cells express specific receptors on their cell membrane, the **B cell receptors** (BCRs). BCRs allow the B cell to bind a specific antigen, against which it will initiate an antibody response.

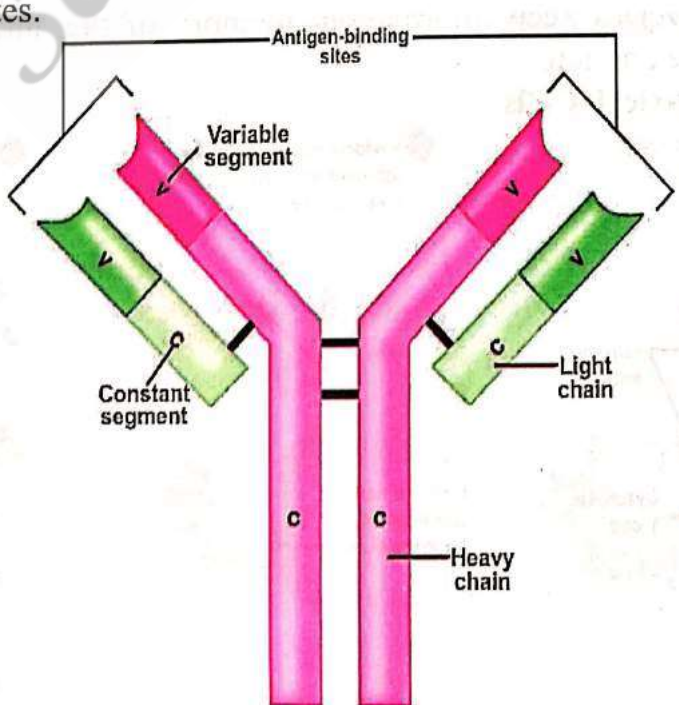
Antibodies

- **Antibodies/Immunoglobulins** are globular proteins, manufactured by B-lymphocytes, then secreted into the lymph and blood where they circulate freely.
- These are Y-shaped molecules and ***possess quaternary structure***.
- Each antibody consists of four polypeptide chains; ***two heavy chains*** and ***two light chains***.
- Each chain has a constant region and variable region.
- In constant region, the amino acid sequence is constant within a particular immunoglobulin class.
- Variable segment consists of different amino acid sequence in every antibody. Therefore, they act as antigen binding sites. Each antibody has two antigen binding sites.

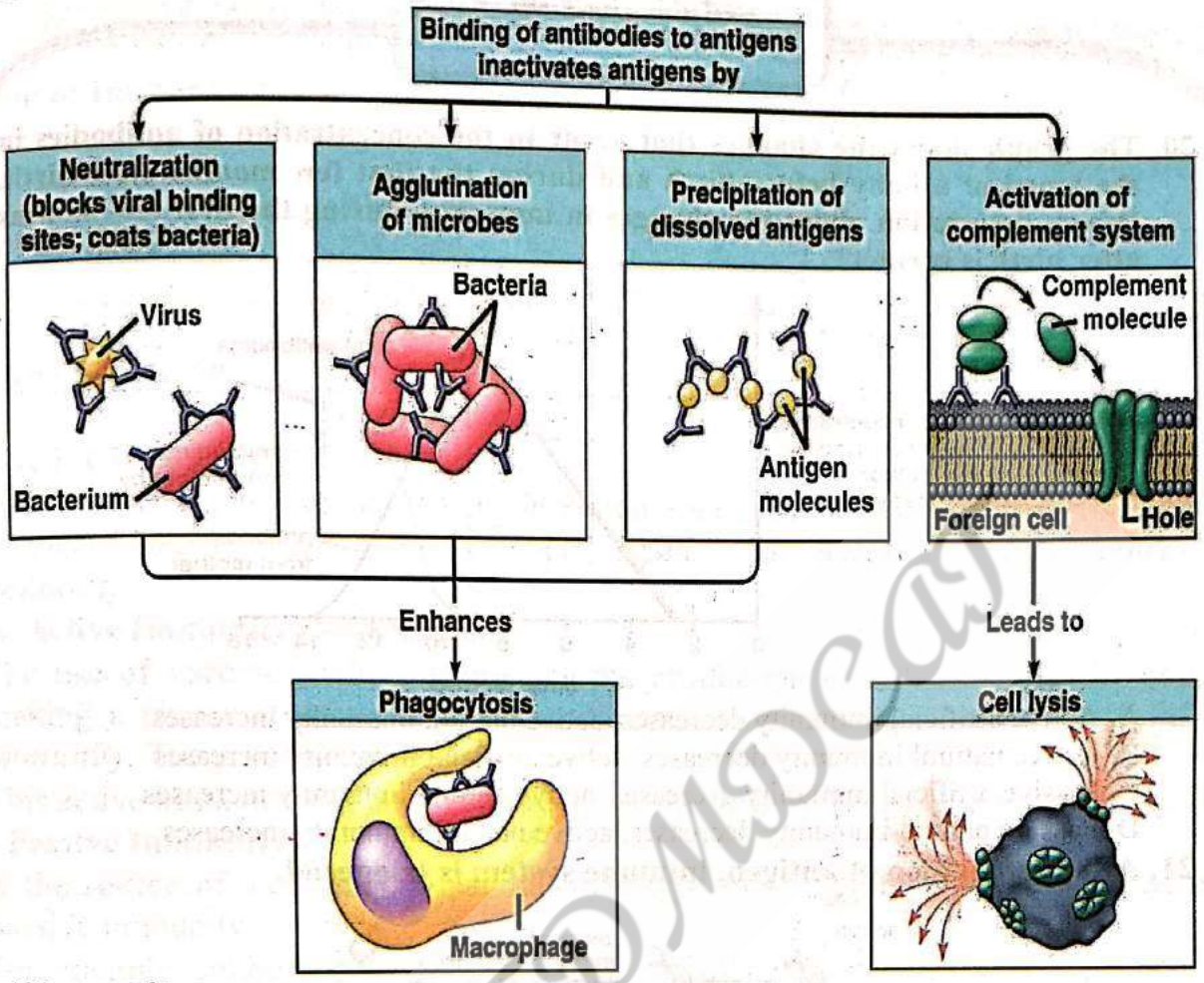
CRITICAL CONCEPT!

Classes of Antibodies and their Important Functions:

IgA plays a role in localized defense mechanism in external secretions like tears.
IgD in involved in recognition of antigens by B-lymphocytes.
IgE is involved in allergic reactions.
IgG is responsible for complement fixation.
IgM is also responsible for complement fixation.



Modes of Action of Antibodies



Types of Immunity

- There are two basic types of immunity: ***inborn*** or ***innate immunity*** and ***acquired*** or ***adaptive immunity***.

Innate Immunity

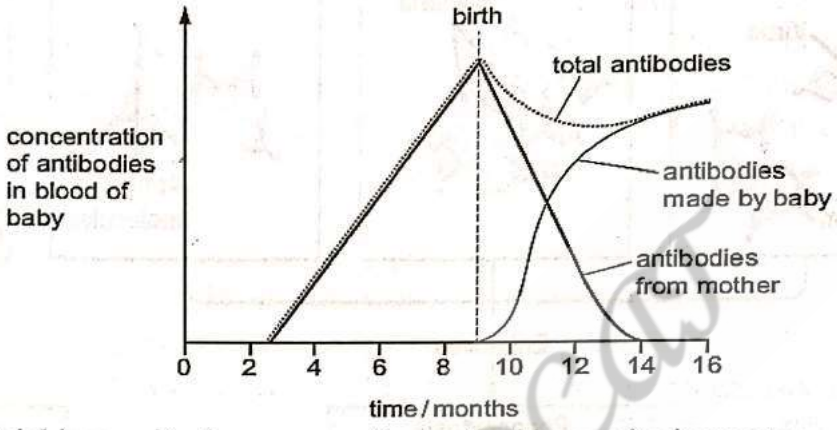
- The ability of the innate immunity to kill microorganisms is not specific.
- First and second lines of defense are part of innate immunity.

Acquired Immunity

- Highly specific protection is provided by innate immunity, but it takes several days for this system to become fully functional.
- There are two types of acquired immune responses i.e. cell-mediated response and antibody-mediated or humoral immune response.
- T-cells recognize antigen and then combat microorganisms and also responsible for rejection of foreign transplanted tissue if it is not properly matched. This is called ***cell mediated response.***
- B-cells recognize antigen and form plasma cell clone. These plasma cells synthesize and liberate antibodies into the blood plasma and tissue fluid. Here antibodies attach to the surfaces of bacteria and speed up their phagocytosis. Some antibodies behave as antitoxins for neutralization of toxins produces by microorganisms. This is called ***humoral immune response.***

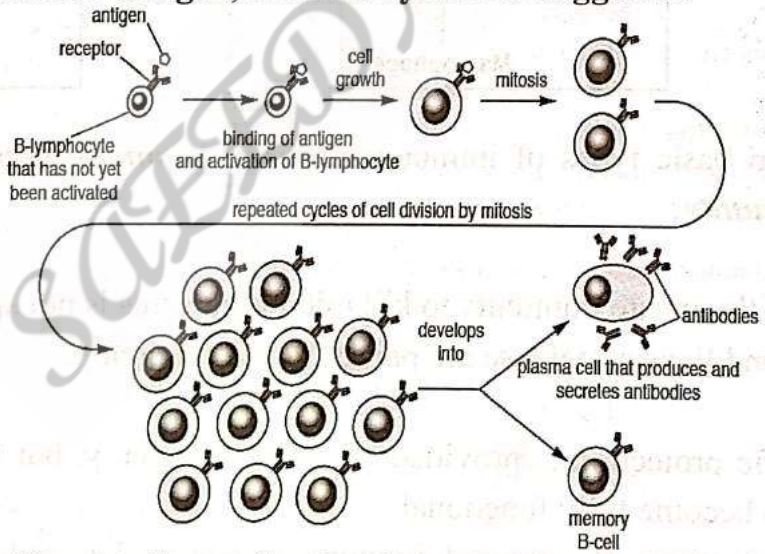
CRITICAL THINKING

20. The graph shows the changes that occur in the concentration of antibodies in the blood of a baby before birth and during the first few months after birth. Which description about the changes in immunity during the first few months after birth is correct?



A. Active artificial immunity decreases, active natural immunity increases
B. Active natural immunity decreases, active artificial immunity increases
C. Passive artificial immunity decreases, active natural immunity increases
D. Passive natural immunity decreases, active natural immunity increases

21. After recognition of antigen, immune system is triggered.



Which type of immunity production is shown?

A. Innate immunity
B. Active immunity
C. Cell mediated Immunity
D. Passive immunity

Types of Acquired Immunity

- There are two types of acquired immunity:

(i) Active Immunity
(ii) Passive Immunity

- The method of passive immunization is used to combat active infections of tetanus, infectious hepatitis, rabies, snakebite

- These are further divided into natural and artificial immunity.

Feature	Active Immunity	Passive Immunity
Production of Immunity	Produced because of entry of antigen.	Produced because of entry of antibodies.
Source of Antibodies	Body is stimulated to produce antibodies.	Antibodies are introduced from other source.
Substance Entering	Antigen	Antiserum
Response	Delayed immune response	Immediate immune response
Results	Prolonged results	Short acting
Memory cell production	Yes	No
Role	Preventive	Preventive and curative

Natural Active Immunity

- When a person is exposed to an infection (antigen) becomes ill and in most cases survives, then this immunity developed against that disease is called ***natural active immunity***.

Artificial Active Immunity (Vaccination)

- The use of vaccines, which stimulates the production of antibodies in the body, and making a person immune against the diseases or infection, is called ***artificial active immunity***. The process is called vaccination.
- This active immunity has been achieved by artificially introducing; antigens in the body.

Natural Passive Immunity

- If the source of antibodies is natural, then type of immunity will be called as natural passive immunity.
- For example, antibodies from a mother can cross the placenta and enter her fetus. In this way they provide protection for the baby until its own immune system is fully functional.
- This immunity may also be provided by ***colostrum***, the first secretion of the mammary glands. The baby absorbs the antibodies through its gut.

Artificial Passive Immunity

- Antibodies which have been formed in one individual are extracted and then injected into the blood of another individual.
- In the case of snakebite venom, passive immunity is produced by antitoxins, so the serum is called anti-venom serum.
- Similarly, specific antibodies used for combating tetanus and diphtheria are cultured and injected into humans.

TOPIC-10 PROKARYOTES (KINGDOM MONERA)

COURSE CONTENT

- Bacteria (Size and Shape)
- Bacterial Cell Structures (Cell envelope)
- Bacterial Cell Structures (Cell membrane onwards)
- Importance and Control of Bacteria

BACTERIA (SIZE AND SHAPE)

- **Bacteria** are microscopic, single-celled organisms that thrive in diverse environments.

Size of Bacteria

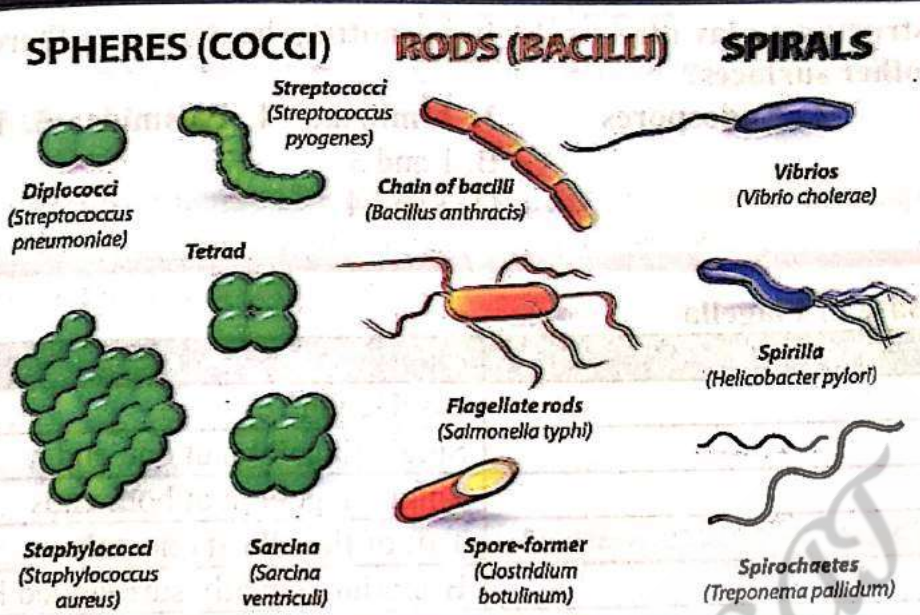
Type	Size
Range	0.1-600 μm
Mycoplasma (Smallest)	100-200 nm
Escherichia coli	1.1-1.5 μm (width), 2.0-6.0 μm (length)
Spirochete	500 μm in length
Staphylococci & Streptococci	0.75-1.25 μm in diameter
Epulopiscium fishelsoni	600 μm x 80 μm

Shapes of Bacteria

- Bacteria may be **Cocci** (Spherical or oval in shape), **Bacilli** (Rod shaped) and **Spiral** (Curved/ spring shaped).
- Some have characteristic shapes; others are ***pleomorphic*** (variable shape).

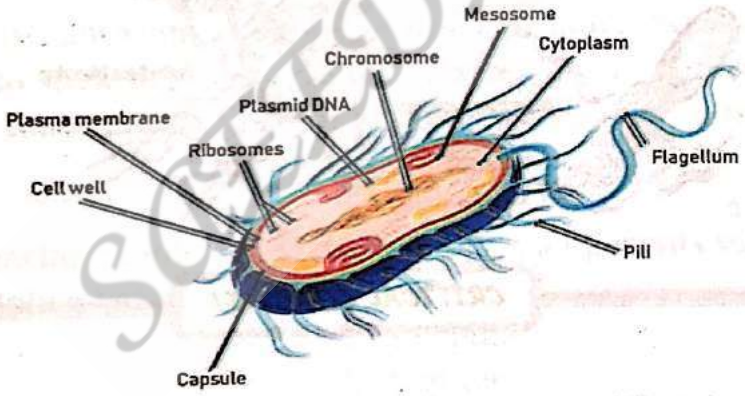
Type	Arrangement	Division	Examples
Coccus	Spherical	No	*Streptococcus pneumoniae, Neisseria meningitidis, Staphylococcus aureus*
Diplococcus	Two cocci	Single plane of division	
Streptococcus	Cocci in chain	Single plane of division	
Staphylococcus	Irregular arrangement	Random planes	
Tetrad	Group of four	Two planes of division	
Sarcina	Group of eight	Three planes of division	
Bacillus	Rod shaped	No	*Escherichia coli, Bacillus subtilis, Pseudomonas*
Diplobacillus	Two bacilli	Single plane of division	
Streptobacillus	Chain of bacilli	Single plane of division	
Coccobacilli	Rod shaped with spherical ends	No	
Spirals	Spirally coiled	No	*Vibrio, Hyphomicrobium, Helicobacter, Treponema*
Vibrio	Comma shaped	No	
Spirillum	Thick, rigid spiral	No	
Spirochete	Thin, flexible spiral	No	

BACTERIA SHAPES



BACTERIAL CELL STRUCTURE

- All bacterial cells invariably have a cell membrane, cytoplasm, ribosomes and chromatin bodies.
- The majority have **cell wall,** which gives shape to the bacterial cell.
- **Specific structures** like capsule, slime, flagella, pili, fimbriae and granules are not found in all bacteria.



Flagella and Pili

Flagella	Pili/ Fimbriae
Thin	Thick
Long	Short
Flexible, Helical	Rigid, Non-helical, Hollow
Originate from basal bodies, attached with plasma membrane & pass out through cell wall.	Originate from basal bodies, attached with plasma membrane & pass out through cell wall.
Made of Flagellin protein	Made of pilin protein
Present in all except cocci. Cocci rarely have flagella.	Present in Gram negative bacteria while absent in Gram positive bacteria.
Help in locomotion/ motility/ chemotaxis.	Involved in attachment with host or with other bacterium for conjugation (Sex/F pili)

CRITICAL THINKING

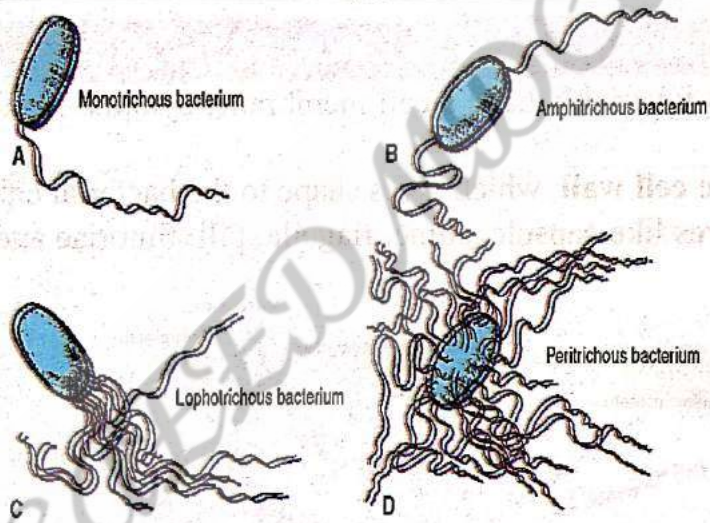
1. **Which two structures play direct roles in permitting bacteria to adhere to each other, or to other surfaces?**

1. Capsules **2. Endospores** **3. Fimbriae** **4. Plasmids** **5. Flagella**

A. 1 and 2 B. 1 and 3
C. 2 and 3 D. 3 and 4

Classification on Base of Flagella

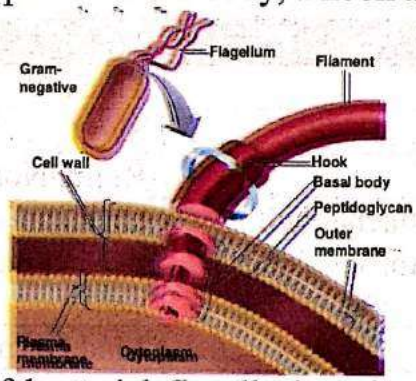
Type	Flagella
Atrichous	No flagella
Monotrichous	Single flagellum at one end
Amphitrichous	Single flagellum at both ends
Lophotrichous	Tuft of flagella at one pole
Peritrichous	Bacterium equally surrounded by flagella



CRITICAL CONCEPT!

Basal Body:

Bacterial flagella consist of three parts: a basal body, a hook and a filament.



The mechanism of movement of bacterial flagella is quite different from eukaryotic flagella. Its basal body produces rotatory motion. The 360° rotation of paired discs enable the flagellum to rotate which in turn causes the cell to spin and move forward.

Cell Envelope

- Complexes of layers external to the cell protoplasm are collectively called cell envelope and commonly include capsule, slime and cell wall.
- Capsule and slime form glycocalyx (Composed of polysaccharide mainly, sometimes proteins are present).

Capsule

- A **thick, gummy** structure giving sticky character to colonies of encapsulated bacteria.
- It is made up of **polysaccharide** units or **proteins** or both.
- It is tightly bound to the cell.

Slime

- **Loose soluble** shield of macromolecules outside capsule is called slime capsule.
- It can be removed from cell easily.
- Slime provides greater **pathogenicity** to bacteria.
- It protects them from **phagocytosis**.

Functions of Glycocalyx
In the form of slime, it prevents the phagocytosis of bacteria by the cells of immune system called **macrophages** by increasing diameter of bacteria and hiding bacterial components from immune system
Promotes the adhesion of the bacteria to living and inert surfaces and the subsequent formation of adherent, glycocalyx-enclosed populations that are called biofilms

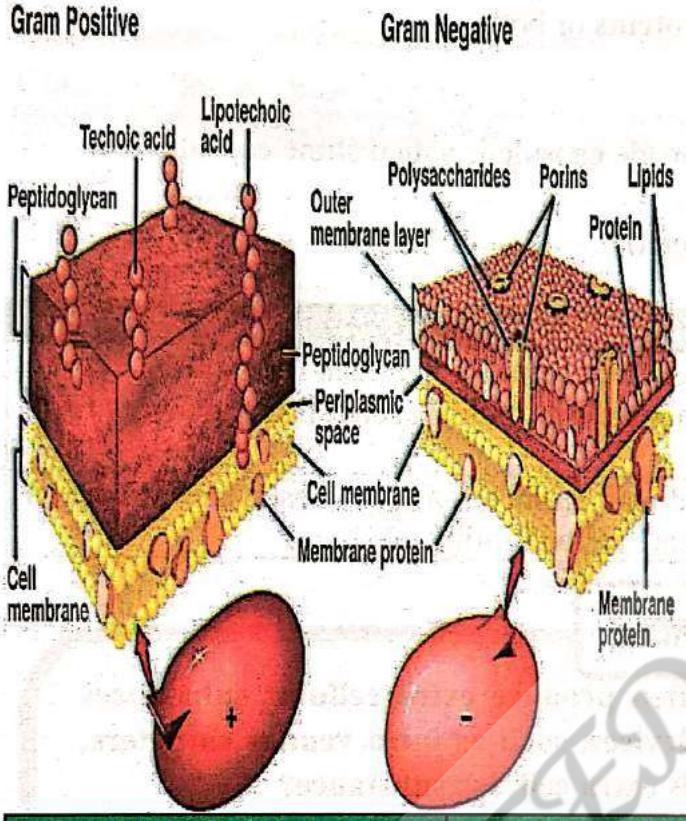
CRITICAL THINKING

2. **Bacteria that cause nosocomial infection often produce extra cellular substances that allow them to stick firmly to medical devices, such as intra venous catheters. Which one of the following is the name of this extra cellular substance?**
 A. Axial filament B. Endotoxin
 C. Flagella D. Glycocalyx
3. **Which of the following requires ATP to function, and permits some species to respond to taxes (plural of taxis)?**
 A. Endospore B. Sex pilus
 C. Flagellum D. Capsule

Cell Wall

- A rigid structure between extracellular substances and cytoplasmic membrane.
- Cell wall is only absent in *Mycoplasma*.
- It is composed of a macromolecule called **peptidoglycan** consisting of long glycan chains cross linked with peptide fragments.
- **Sugar, teichoic acid, lipoproteins and lipopolysaccharides** are also present which are linked with peptidoglycan.
- Teichoic acid fibers protrude outside the peptidoglycan.
- Cell wall of archaebacteria does not contain peptidoglycan; rather contain proteins, glycoproteins and polysaccharides.
- It determines the **shape of bacteria**.
- It **protects** the cell from **osmotic lysis**.

- It provides **identity to different bacteria**, depending upon their staining characteristics i.e., Gram positive and Gram negative bacteria.
- The Gram-negative cell wall also contains a protein, the **porins** in outer membrane which act like pores for particular molecules.



CRITICAL CONCEPT!

Peptidoglycan:
Chemically, Peptidoglycan is a conjugated molecule, consisting of two alternating amino sugars make up the crystal lattice structure of peptidoglycan; they are N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM). Amino sugars are sugar molecules that have an amine group ($-NH_2$) replacing one of their hydroxyl groups. Each NAM molecule has an attached chain of four or five amino acids. Crosslinking between these amino acids gives peptidoglycan its strong structure.

Characteristics	Gram Positive	Gram Negative
Stain	Primary dye (Crystal violet & Gram's iodine)	Secondary dye (Safranin)
Staining character	Purple	Pink
Number of major layers	1	2
Peptidoglycan	50% of dry weight	10% of dry weight
Lipids	1-4%	11-12%
Additional substances	Teichoic acid and lipoteichoic acid	Lipopolysaccharides, lipoproteins
Overall thickness	Thick 20-80 nm	Thin 8-11 nm
Outer membrane	No	Yes
Periplasmic space	Present in some	Present in all
Permeability	More permeable	Less permeable
Resistance	More	Less

- Periplasmic space lies between peptidoglycan layer of cell wall and cytoplasmic membrane. It is the site having certain enzymes.

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CRITICAL CONCEPT!

Gram staining procedures:
The performance of the Gram Stain on any bacterial sample requires four basic steps that include:

1. Applying a primary stain (crystal violet) to a heat-fixed smear
2. Addition of a mordant (Gram's Iodine)
3. Rapid de-colorization (with alcohol etc.)
4. Counterstaining with safranin

Cell Membrane

- It is thin, flexible structure beneath the cell wall, surrounding cytoplasm.
- It is very delicate in nature and any damage to it results in death of the organism.
- Bacterial membrane differs from eukaryotic membrane in **lacking sterols** such as cholesterol.
- It is involved in **transport** of proteins, nutrients, sugars and electrons or other metabolites.
- The plasma membrane of bacteria also contains **enzymes for respiratory metabolism i.e.,** site for cellular respiration.

CRITICAL THINKING

4. Pick the correct one regarding cell membrane:

	Features	Prokaryotes	Eukaryotes
A.	Help in flow of nerve impulse	Yes	Yes
B.	Lacks cholesterol	Yes	Yes
C.	Helps in transport of material	Yes	Yes
D.	Proteins are embedded in membrane	No	Yes

Cytoplasmic Matrix

- A **gel like** substance present between the plasma membrane and the nucleoid.
- Plasma membrane and everything present within it is called **protoplast**.
- Cytoplasmic matrix lacks membrane bounded organelles and cytoskeleton however chromatin/ nuclear body, ribosomes, mesosomes, granules and nucleoid are present in it.

Nucleoid

- Bacteria like other prokaryotic cells lack definite membrane bounded nucleus and chromosomes.
- Nucleoid is a single, circular, double stranded DNA molecule, aggregates as an irregular shaped dense area in the centre of bacterial cell.
- It is visible in the light microscope after staining with Feulgen dye.
- Other names for nucleoid are nuclear body, chromatin body and nuclear area.
- Extremely long molecule of DNA that is tightly folded to fit inside the cell component is chromatin body.
- Bacteria have a single chromosome; thus, they are **haploid**.
- *E. coli* closed circle chromosome measures approximately 1,4000 μm.

Plasmid

- Circular, double stranded DNA molecules, **self-replicating** but not essential for the bacterial growth and metabolism
- Contains genes of **drug resistance, heavy metal resistance, disease, and insect resistance.**
- Plasmids are important vectors in modern genetic engineering techniques.

Ribosomes

- **Smaller** than eukaryotic ribosome.
- They are composed of **RNA and proteins.**
- May be loosely attached to the cell membrane or plasma membrane.
- They are involved in protein synthesis.

Mesosomes

- Formed by **invagination of cell membrane** in to the cytoplasm.
- Involved in DNA replication, cell division, export of exo-cellular enzymes and also contain respiratory enzymes.

Storage Bodies and Granules

- Store **extra nutrients** like glycogen, sulphur, fat and phosphate.
- Also store **waste material** like alcohol, lactic acid, and acetic acid.

Spores

- These are **metabolically dormant** bodies, resistant to adverse physical environmental conditions such as light, high temperature, desiccation, pH and chemical agents.
- They may be **exospores** (external to vegetative cell) or **endospores** (inside vegetative cell/ inside cell wall).
- Endospores are more resistant structures and can survive for years.
- They **germinate** to form vegetative cell under favorable conditions.
- They normally develop at **end stage of growth** of bacteria.

Cysts

- They are **dormant, thick walled** desiccation resistant form but not heat resistant structures.
- They develop during **differentiation of vegetative cells** which can germinate under suitable conditions.

Spore	Cyst
Inside (Endospores)	Outside
Resistant to light, temperature, desiccation, pH and chemical agents	Desiccation resistant
Develops at end stage of bacterial growth	Develops during differentiation of bacterial cell.
Actinomycets	*Azotobacter*

IMPORTANCE AND CONTROL OF BACTERIA

Importance of Bacteria

Ecological Importance

- Bacteria are ecologically very important. They are highly adaptable as a group and are found nearly everywhere.
- They are able to decompose organic matter and play a significant role in the completion of cycles of nitrogen, phosphorus, sulfur and carbon.
- Bacteria help in bioremediation.

Economic Importance

- Bacteria are used in number of industries, including food, drugs (production of antibiotics) and in biotechnology.
- Bacteria are also responsible for spoilage of food and vegetables.
- Many plant pathogens adversely affect the agricultural industry.

Medical Importance

- Bacteria are very common pathogens of humans. **Approximately 200 species** are known to cause diseases in humans.
- Many bacteria normally inhabit the bodies of man and other animals.

Control of Bacteria

Bacterial control is required to prevent diseases and food spoilage.

Physical Methods

- The process in which physical agents are used to control bacteria/microorganisms is known as **sterilization process.**
- It involves killing of all microbes.
- In physical methods, steam, dry heat, gas, filtration and radiations are used to control bacteria.

(i) Use of Heat

- Both dry heat and moist heat are effective.
- Moist heat causes coagulation of proteins and kills the microbes.
- Dry heat causes oxidation of chemical constituents of microbes and kills them.

(ii) Use of Radiations

- Certain electromagnetic radiations below 300 nm are effective in killing of microorganisms.
- Gamma rays are in general used for the sterilization process.

(iii) Membrane Filters

- Heat sensitive compounds like antibiotics, seras etc. can be sterilized by means of membrane filters.

(iv) Pasteurization

(v) Low Temperature

(vi) Freezing

(vii) Preservatives

Chemical Methods

(i) Disinfection

- It involves killing of microbes by use of chemical agents.
- It involves killing of most but not all life forms.
- The important chemicals used for disinfection are oxidizing and reducing agents. For example, halogens, phenols, hydrogen peroxide, potassium permanganate, alcohol and formaldehyde etc.

(ii) Antisepsis

- Procedure to eliminate or reduce the possibility of infection is called antisepsis.
- Chemical substances used on living tissues that inhibit the growth of microorganism are called antiseptics.

(iii) Chemotherapeutic Agents

- Chemotherapeutic agents and antibiotics work with natural defense and stop the growth of bacteria and other microbes. These are sulfonamides, tetracycline and penicillin.
- They destroy or inhibit the growth of microorganisms in living tissues.

(viii) Vaccination

- Vaccination is an important method to control bacterial diseases in humans.
- Pasteur used attenuated cultures of bacteria as vaccine.

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TOPIC-11 » REPRODUCTION

COURSE CONTENT

- Male Reproductive System
- Female Reproductive System
- Menstrual Cycle
- Sexually Transmitted Diseases

MALE REPRODUCTIVE SYSTEM

Gonads

- Male gonads consist of a ***pair of testes***, which lie outside the body, in sac-like scrotum.
- Each testis consists of a highly complex duct system called seminiferous tubules, in which repeated division by the cells of the germinal epithelium produces spermatogonia.
- Seminiferous tubules also contain ***sertoli cells/nurse cells***, which provide liquid medium, protection and nourishment to sperms while they are in the tubules. These cells also secrete inhibin hormone which serves to control the spermatogenesis at normal rate.
- ***Interstitial cells/leydig cells*** are present between the seminiferous tubules and secrete testosterone essential for production of sperms and development of male secondary sexual characteristics during puberty.
- Both germinal epithelial cells and sertoli cells are under the control of FSH while interstitial cells are under the control of ICSH.

External Genitilia

- ***Penis*** is copulatory organ and external genitalia, which is used to transfer sperm into female reproductive tract.

Duct System

- ***Seminiferous tubules*** are the sites for spermatogenesis.
- ***Epididymis*** is the proximal highly convoluted portion of vas deferens where maturation of sperms is completed, they become motile and are stored.
- ***Vas deferens*** (sperm duct) is the main duct of male reproductive tract.
- Part of vas deferens that receives secretions from seminal vesicles is called ***ejaculatory duct***.
- ***Urethra*** in male is also called as urinogenital duct because it transfers both urine and semen outside the body.

Glands

- Testes are endocrine glands which are paired and produce male sex hormones, most important of which is testosterone.

CRITICAL CONCEPT!

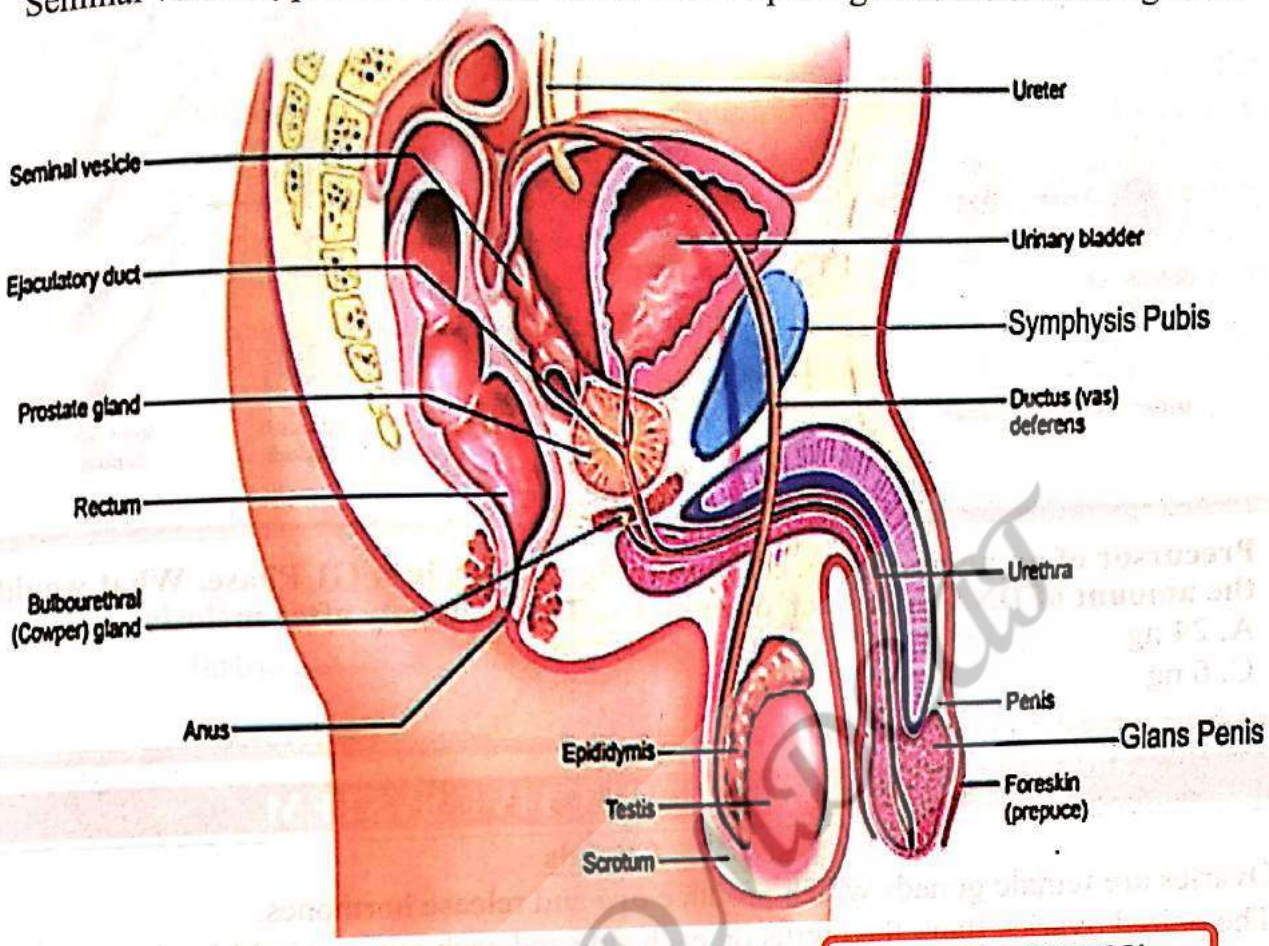
Role of Accessory Glands in Male Reproductive System:

Seminal vesicles: The seminal vesicles provide an alkaline fluid containing fructose, ascorbic acid and a coagulating enzyme called vesiculase, as well as other substances that enhance the sperm motility thus improve their fertilizing power.

Prostate gland: The prostate encircles the urethra just below bladder, its secretion is a milky slightly acidic fluid that contain citrate as a nutrient source and several enzymes specially hyaluronidase.

Bulbourethral gland (Cowper's gland): It secretes mucus and alkaline fluid into urethra. This fluid neutralizes the acidity of urine in urethra.

- Seminal vesicles, prostate and bulbourethral/Cowper's glands are exocrine glands.

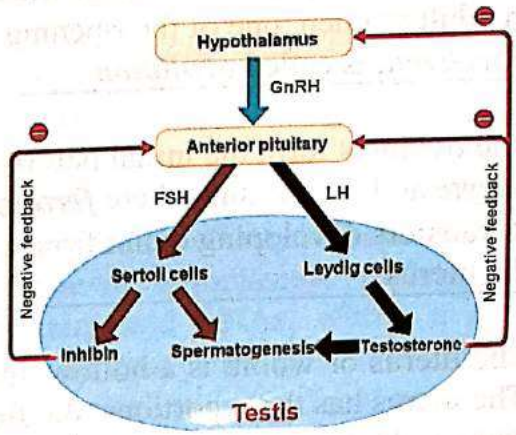


Spermatogenesis

- Spermatogonia increase in size and differentiate into primary spermatocytes which undergo meiotic division to form secondary spermatocytes and spermatids.
- Eventually spermatids differentiate into mature sperms.
- The sperms are then transferred to the main duct of the male reproductive tract, the vas deferens, which forms highly convoluted epididymis.
- The sperms then pass through the urino-genital duct and are discharged out.

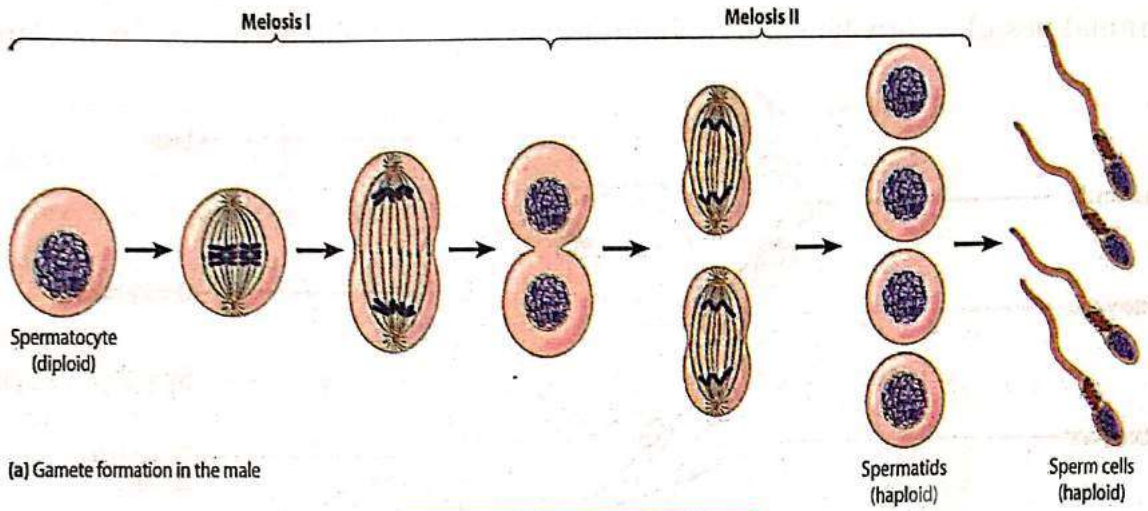
CRITICAL CONCEPT!

Hormonal Control of Spermatogenesis



CRITICAL CONCEPT!

Semen:
It is a white, sticky mixture of sperm and secretions of accessory glands. The liquid in semen provides nutrients and protection to sperms and acts as transport medium for sperms.



(a) Gamete formation in the male

CRITICAL THINKING

1. **Precursor of an animal germ cell has 12 ng of DNA in it G1 Phase. What would be the amount of DNA in its each daughter cell immediately after meiosis?**
 A. 24 ng B. 12 ng
 C. 6 ng D. 3 ng

FEMALE REPRODUCTIVE SYSTEM

1. Gonads

- Ovaries are female gonads which produce ***ova*** and release hormones.
- The paired ovaries flank the uterus on each side and each ovary is held in place within the peritoneal cavity by several ligaments.
- The ovaries are solid, ovoid structures. Within the ovary are many tiny saclike structures called ***ovarian follicles*** each of which consists of an immature egg, called an **oocyte**.
- In adult women, one of the ripening follicles ejects its oocyte from the ovary each month. This event is called ***ovulation***.

2. Oviducts

- The oviducts form the initial part of the female duct system. They receive the ovulated ***oocyte*** and are the site where ***fertilization*** generally occurs.
- It transfers developing ovum from ovary towards the uterus. The oocyte is carried toward the uterus.

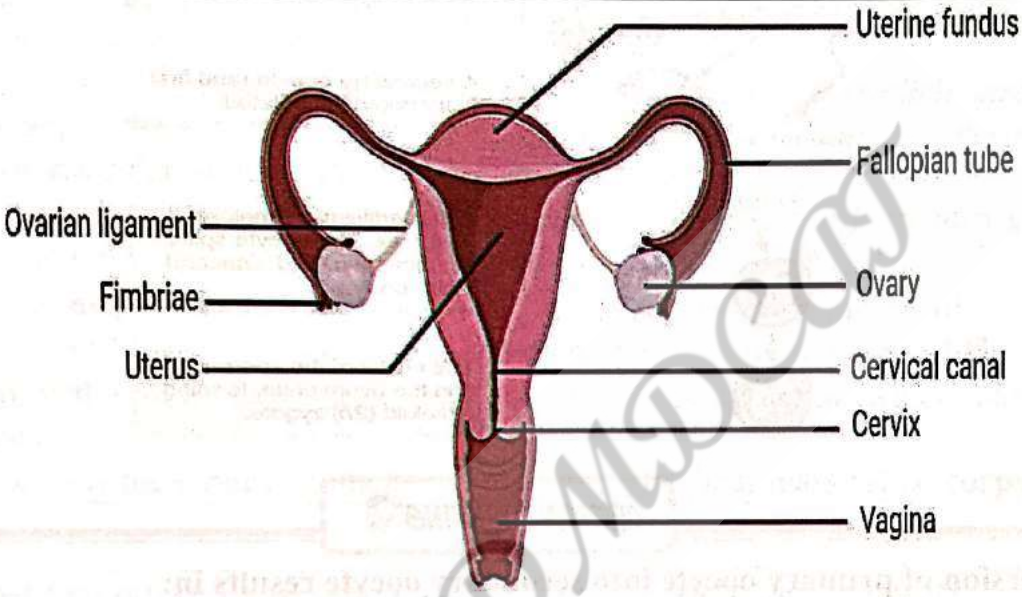
3. Uterus

- The uterus or womb is a hollow, muscular organ, shaped somewhat like an inverted pear. The uterus has three portions: the ***fundus***, the ***body*** and the ***cervix***.
- The oviducts join the uterus just below the fundus and the opening of the cervix leads to the vaginal canal.
- **Cervix** is a narrow entrance to the uterus from the vagina. It is normally blocked by a plug of mucus.
- The wall of the uterus is composed of three layers;

4. Vagina

- The vagina (opening is called vulva) is a thin-walled long tube and extends from the cervix to the body exterior.
- Vagina is often called the ***birth canal*** as it provides a passageway for delivery of an infant

and for menstrual flow. The urethra is embedded in its anterior wall.	
Perimetrium	The perimetrium is the outermost thin covering layer of the uterus.
Myometrium	The myometrium is the middle thick muscular layer composed of bundles of smooth muscle, which contracts rhythmically during childbirth to expel the baby from the mother's body.
Endometrium	The endometrium is the inner spongy lining of the uterine cavity. If fertilization occurs, the young embryo is implanted into the endometrium and resides there for the rest of its development. The main functions of uterus are to receive, retain, and nourish a fertilized ovum.



Oogenesis

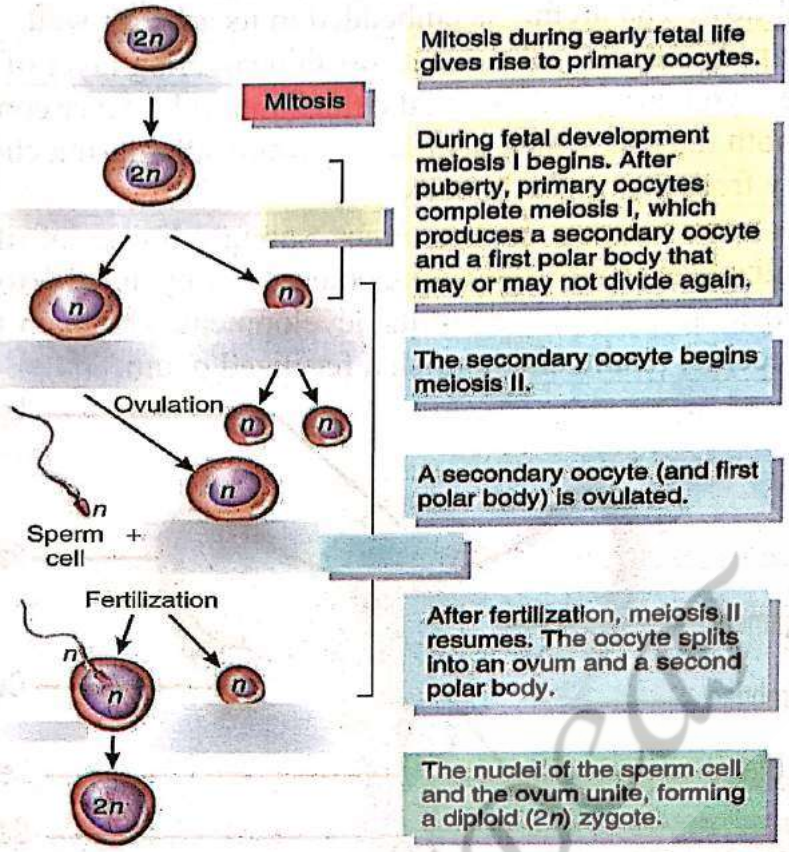
- Gametogenesis in the female is known as oogenesis and result in the formation of ova/egg.
- Oogenesis starts before birth when ***oogonia*** divide mitotically to produce primary oocytes.
- These primary oocytes are enclosed in groups of ***follicle cells***.
- Primary oocytes undergo through meiosis-I but are ***arrested at prophase-I***.
- At puberty, primary oocyte completes meiosis-I and gives rise to haploid secondary oocyte along with ***1st polar body***.
- Secondary oocyte undergoes through meiosis-II but arrested in metaphase-II. It is released in this stage from ovary and does not proceed further until fertilized.
- If fertilization occurs, then secondary oocyte divides to form ovum and 2nd polar body.
- In human female only one ovum is usually discharged from the ovary at one time, this phenomenon is called ovulation.

CRITICAL CONCEPT!

Asymmetric Segregation During Oogenesis:

Asymmetric segregation of cellular determinants is based on the asymmetric localization of cytoplasmic molecules, e.g., proteins and RNAs, within a cell before it divides. During cell division, one daughter cell receives most or all of the localized molecules, while the other daughter cell receives less or none of these molecules. This results in two different daughter cells, which then take on different cell fates based on differences in gene expression.

SCIENCE MOCOS



CRITICAL THINKING

2. Conversion of primary oocyte into secondary oocyte results in:

A. Reduction in amount of DNA only
B. Reduction in DNA and chromosomes
C. Reduction in chromosomes only
D. Reduction in chromatids only

MENSTRUAL CYCLE

- In female, production of egg is a cyclic activity as compared to male.
- ***Oestrous cycle*** is reproductive cycle in all mammalian female except humans. In human female, it is called ***menstrual cycle***.
- Menstrual cycle involves changes in the structure and function of the whole reproductive system.
- 1st ovulation and menstruation occur at puberty. Start of menstrual cycle is called ***menarche***. Its complete stop or end is called ***menopause***. It is completed in approximately 28 days.
- The events of the menstrual cycle involve the ovaries (ovarian cycle) and the uterus (uterine cycle). Events of menstrual cycle are regulated by ***pituitary gonadotrophins***.

CRITICAL CONCEPT!

Pregnancy Test:

A pregnancy test can tell whether a female is pregnant or not. It is done by checking for a particular hormone in the urine or blood. This hormone is called human chorionic gonadotropin (hCG). hCG is synthesized by the trophoblasts, cells that formed outer layer of blastocyst.

Menstrual Phase (Days 1–5)

- In this phase, the uterus sheds all but the deepest part of its ***endometrium***.
- The thick, hormone-dependent functional layer of the endometrium detaches from the uterine wall, a process that is accompanied by bleeding for 3–5 days.
- The detached tissue and blood pass out through the vagina as the ***menstrual flow***.
- At the beginning of this stage, ovarian hormones are at their lowest normal levels and gonadotropins are beginning to rise. Then ***FSH levels begin*** to rise.

Proliferative/Pre-Ovulatory Phase (Days 6–14)

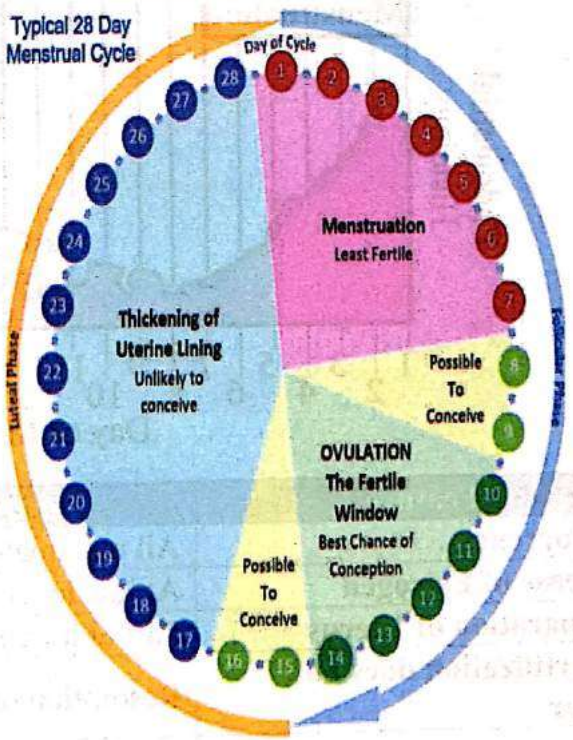
- Follicle stimulating hormone (FSH) during the first days of the cycle stimulates few ovarian follicles.
- Only 1 follicle develops. Rest stop to grow and finally disintegrate (***follicle atresia***), while one dominant follicle in the ovary continue to mature and becomes ***mature follicle*** (Graffian or vesicular follicle), in which ***oogenesis*** occurs.
- FSH also stimulates the graffian follicle to secrete estrogen which in turn governs the vascularization of endometrial lining of uterine wall.
- Estrogen has **negative feedback** upon FSH, therefore, as the concentration of estrogen rises the level of FSH falls. This is a signal for anterior pituitary to release **LH**.
- At the end of the proliferative stage (day 14) LH causes **ovulation** which takes less than five minutes.
- LH also converts the ruptured follicle to a yellowish glandular mass called **corpus luteum**.

Secretory/Post-Ovulatory Phase (Days 15–28)

- During the secretory phase, the endometrium prepares for implantation of an embryo.
- Rising levels of progesterone from the corpus luteum act on the endometrium, causing the arteries to elaborate and converting the functional layer to a glandular secretory layer.
- The uterine glands enlarge, coil and begin secreting nutritious glycogen into the uterine cavity.
- ***If fertilization has not occurred***, the corpus luteum begins to degenerate toward the end of the secretory phase as LH blood levels decline.
- Progesterone levels fall, depriving the endometrium of hormonal support and endometrial cells die, setting the stage for menstruation to begin on day 28.

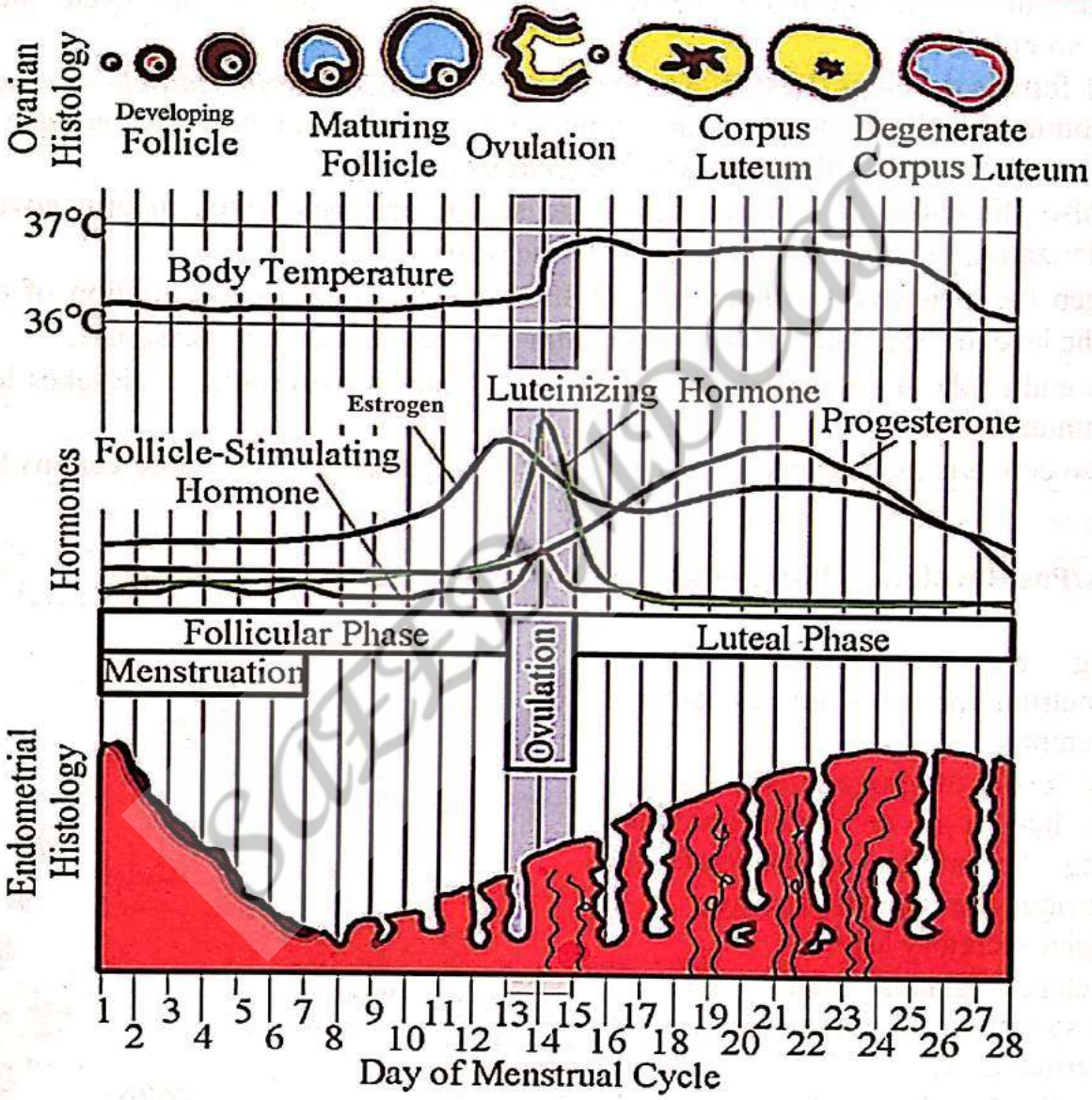
CRITICAL CONCEPT!

Fertile Period:



CRITICAL THINKING

3. **In females, considering menstrual cycle, rapidly rising estrogen levels signify that:**
 A. Ovulation cannot occur
 B. Ovulation has occurred
 C. Ovulation is just to occur
 D. Ovulation is occurring
4. **All of the following hormones are produced by the placenta except:**
 A. Human chorionic gonadotrphin
 B. Human placental lactogen
 C. Progesterone
 D. Luterotrophic hormone



Feature	Oestrous Cycle	Menstrual Cycle
Occurrence	All mammals except human	Human female
Release of Estrogen	At low level	At higher level
Preparation of Uterus	Partial for conception	Fully for conception
If fertilization does not occur	Resorption of endometrium	Destruction and discharge (Menstrual flow)
	Egg is conserved	Egg is released
Ovulation	Requires physical stimulus of mating	Under hormonal control

SEXUALLY TRANSMITTED DISEASES

Feature	Gonorrhea	Syphilis	Genital Herpes	AIDS
Causative Agent	Gram positive bacteria	Spirochete	Virus	Virus
Cause	*Neisseria gonorrhoeae*	*Treponema pallidum*	Herpes simplex type II	HIV
Main parts Affected	Mucous membrane of urinogenital tract, eye infection to baby.	Damage to reproductive organs, eyes, bones, joints, CNS, heart, skin. Infection proceeds in 3 stages	Infection of genitalia, genital soreness & ulcers, damage to eyes & CNS in infants.	Destruction of immune system
Source of Transmission	Sexual contact	Sexual contact	Sexual contact	Sexual contact
Treatment	Antibiotics	Antibiotics	Anti-viral drugs	Anti-viral drugs

SAEED MDCAT

TOPIC-12 » SUPPORT & MOVEMENT

COURSE CONTENT

- Cartilage
- Comparison of Muscle Types
- Structure and Ultra-Structure of Skeletal Muscles
- Sliding Filament Model and Energy for Muscle Contraction
- Types of Joints
- Disorders of Human Skeleton (Gout and Arthritis)

CARTILAGE

CARTILAGE

- It is softer connective tissue than bone.
- It has no blood supply and gets nutrients by diffusion.
- Living cells of cartilage are called chondrocytes.
- Collagen matrix is secreted by chondrocytes.

Major Functions of Bone:

- Protect Vital Organ
- Help in Movement
- Blood Cells Production
- Minerals Homeostasis

Types of Cartilage

(i) Hyaline Cartilage

- Most abundant type in human body
- Found at the movable joints

(ii) Elastic Cartilage

- Matrix containing bundles of collagen fibres
- Forms external ear/ pinnae and the epiglottis

(iii) Fibrocartilage

- Annulus fibrosus of vertebral disc is an example.

Feature	Bone	Cartilage
Cells	Mature cells are osteocytes	Mature cells are chondrocytes
Strengthening Material	Inorganic salts	No
Reshaping	✓	×
Blood Supply	✓	×
Healing	✓	×

TENDON & LIGAMENT

Feature	Tendon	Ligament
Nature	Inelastic connective tissue	Elastic connective tissue
Function	Attaches muscle to bone	Holds bones at joints

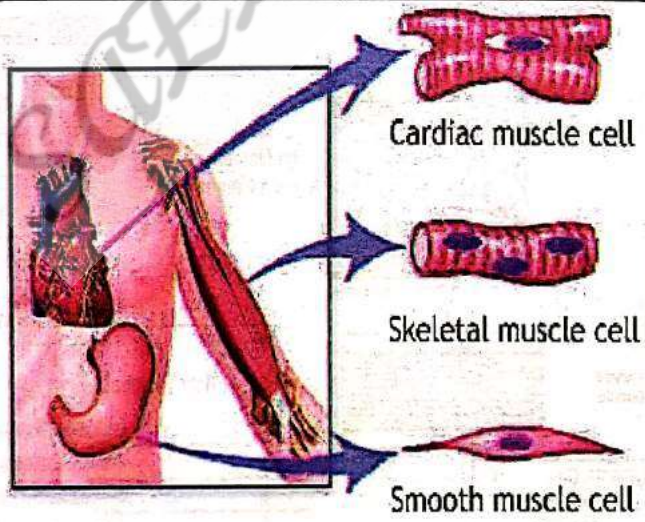
CRITICAL THINKING

1. **It is not true about cartilage and bones:**
 A. Cartilage and bones are types of connective tissues
 B. Blood vessels penetrate cartilages but not bones
 C. Bones have osteocytes and cartilages have chondrocytes
 D. Bones and cartilages have collagen in them

COMPARISON OF MUSCLE TYPES

- Earliest forms of muscles to be evolved are smooth muscles which are present throughout animal kingdom. Smooth muscles show ***peristalsis***.
- Cardiac muscles and skeletal muscles are found only in vertebrates.
- Cardiac muscles have ***intercalated disc***.
- Most abundant type of muscles in human body is skeletal muscles.

Features	Smooth	Cardiac	Skeletal
Muscle appearance	Unstriped (non-striated)	Irregular stripes (striated)	Regular stripes (striated)
Cell shape	Spindle	Branched	Spindle or cylindrical
Number of nuclei	One per cell	One per cell	Many per cell
Speed of contraction	Slow	Intermediate	Slow to rapid
Fatigue	Vary	Never fatigue	Can be fatigued
Contraction caused by	Spontaneous, stretch, nervous system, hormones	Spontaneous	Nervous system
Control	Autonomic (involuntary)	Involuntary	Voluntary
Location	Blood vessels, GIT, other hollow organs	Heart	Associated with skeleton
Function	Controls movement of substances through hollow organs	Pumps blood	Moves the skeleton and heat production



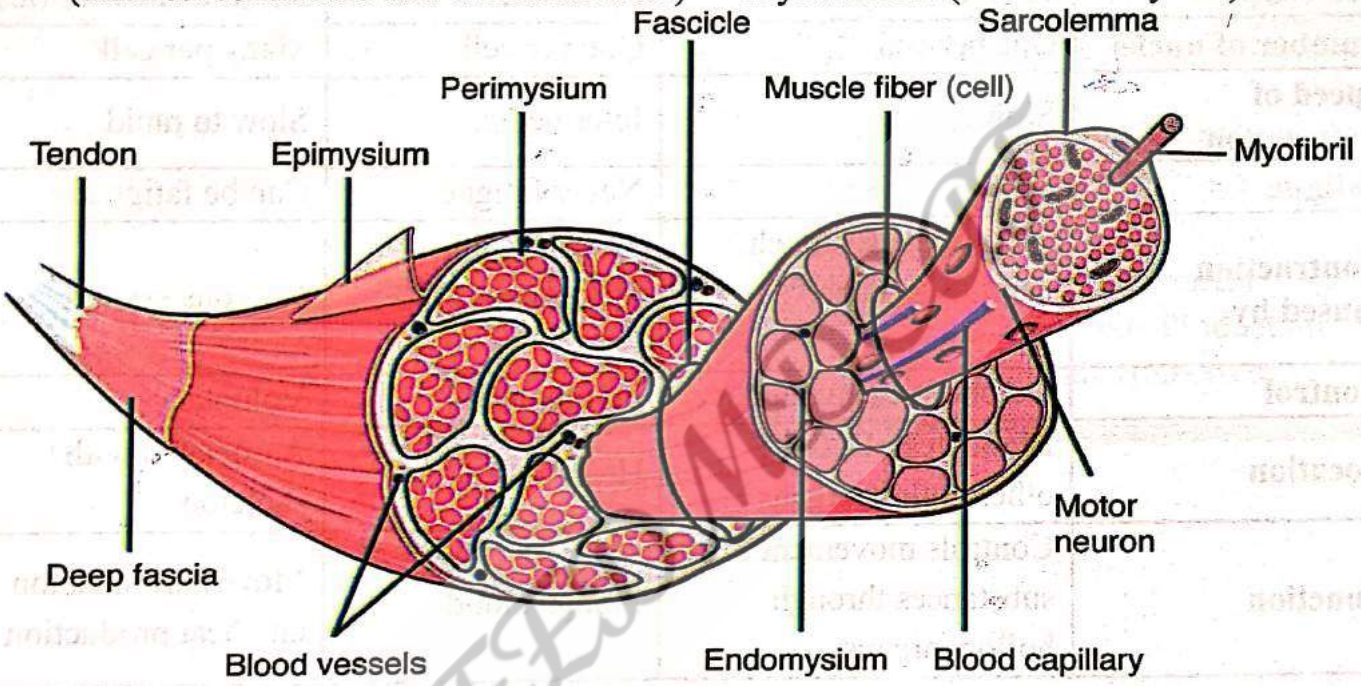
CRITICAL THINKING

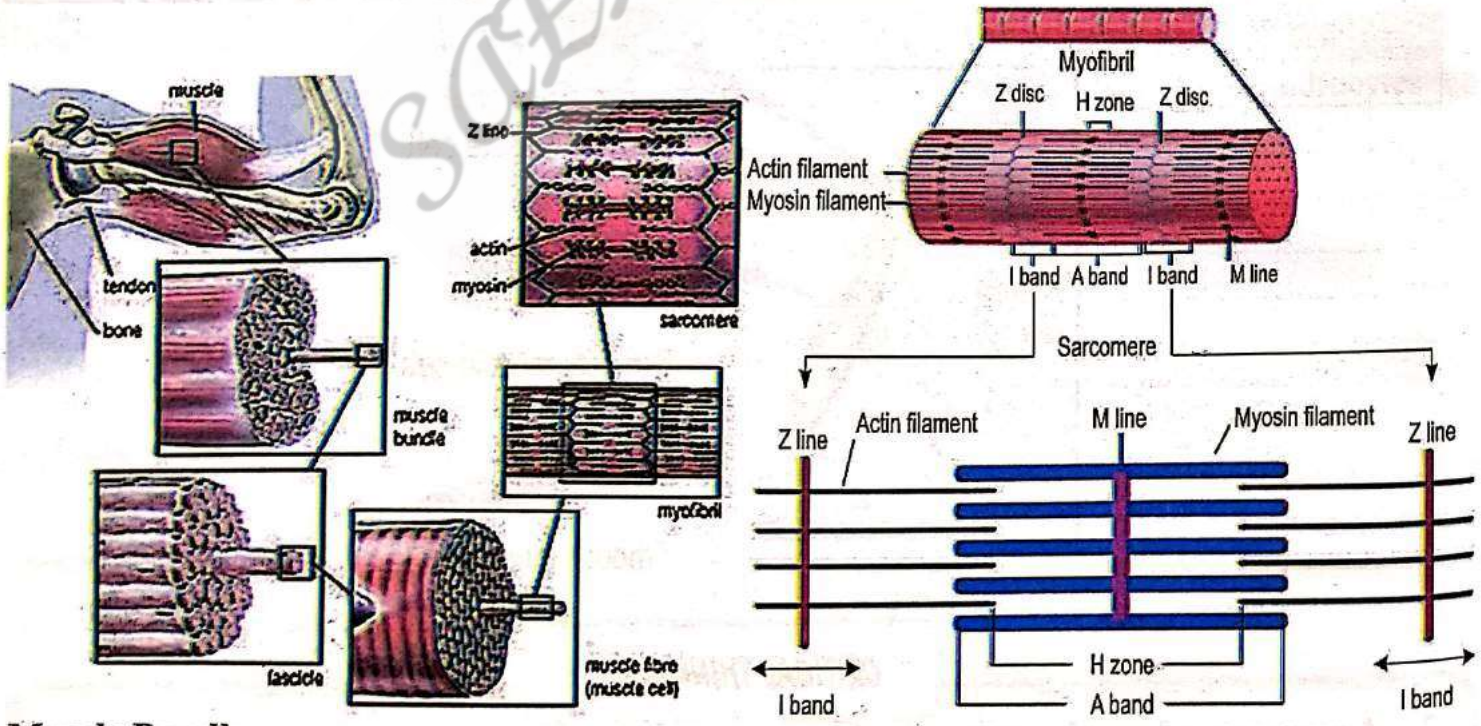
2. A property of cardiac myocytes is:

A. Voluntary control
B. Fatigue resistance
C. Spindle shaped cell
D. Unstripped

STRUCTURE AND ULTRA-STRUCTURE OF SKELETAL MUSCLE

- The muscles that are ***attached to the skeleton*** and are associated with the movement of bones are called skeletal muscles.
- The skeletal muscles are consciously controlled and therefore, are called ***voluntary muscles***.
- Generally, each end of the entire muscle is attached to bone by a bundle of collagen, non-elastic fibers known as ***tendons***.
- The entire muscle is covered by a layer of connective tissue called ***epimysium***.
- Structural scheme of a skeletal muscle is given below:
 Skeletal muscles → Muscle bundles → Muscle fibers → Myofibrils → Sarcomere (smallest contractile unit of muscle fiber) → Myofilament (Actin and Myosin).





Muscle Bundle

- Muscles bundles are also called as ***muscle fasciculi***.
- These are bounded by a connective tissue called ***perimysium***.

- Muscle bundles are further composed of muscle fibers or cells.

Muscle Fibers

- Each muscle fiber is a ***long cylindrical cell*** with ***multiple oval nuclei*** arranged just beneath its sarcolemma.
- Skeletal muscle fibers are huge cells.
- Their diameter is ***10-100 μm***.
- Sarcoplasm of the muscle fiber is similar to the cytoplasm of other cells, but it contains usually large amount of ***stored glycogen*** and unique oxygen binding protein e.g. ***myoglobin***.
- Sarcoplasmic reticulum is continuous system of sarco-tubules extending throughout the sarcoplasm around each myofibril. It is like endoplasmic reticulum but devoid of ribosomes.
- Each muscle fiber further contains large number of myofibrils.

CRITICAL THINKING?

3. A structure around cell that has channels and gates for movement of solute molecules:

A. Epimysium B. Sarcolemma
C. Sarcoplasmic reticulum D. Endomysium

Myofibrils

- Each myofibril is ***1-2 μm*** that run in parallel fashion and extend entire length of cell.
- Bundles of these fibrils are enclosed by the sarcolemma.
- The myofibrils consist of smaller contractile units called ***sarcomere***.
- Myofibril has ***series of dark and light bands***. These give cell as whole its striped appearance.

Ultra-structure of Myofilaments

- Myofilament is made up of thick and thin filament.

(i) Thick Filament

- Thick filament is about ***16nm in diameter*** and is ***composed of myosin***.
- Each myosin molecule has a tail terminating in two globular heads.
- Each thick filament contains about 300 myosin molecules bundled together with their tails forming the central part of the thick filament and their heads facing outward and in opposite directions at each end.
- Myosin tail consists of two long polypeptide chains coiled round each other.
- The heads are sometimes called ***cross bridges*** because they link the thick and thin myofilaments together during contraction.
- Each myosin filament is surrounded by six actin filaments on each end.

(ii) Thin Filaments

- Thin filaments are ***7-8 nm thick*** and are composed of chiefly ***actin molecules***.
- The actin molecules are arranged in two chains which twist around each other like a twisted double strand of pearls.
- The kidney-shaped polypeptide subunits of actin, called globular actin or ***G-actin***, bear the active sites to which the myosin heads attach during contraction. G-actin monomers are polymerized into ***long actin filaments***.

- Twisting around the actin chains are two strands of another protein, ***tropomyosin***. When the muscle is at rest, the tropomyosin is disposed in such a way that it covers the sites on the actin chain where head of myosin become attached.
- The other major protein in thin filament is ***troponin***. It is actually three polypeptide complexes. One (TnC) binds with calcium, one (TnI: Inhibitory Subunit) with actin and one (TnT) with Tropomyosin and helps position it on actin.

CRITICAL CONCEPT!

Biomarker of Heart Attack:
Myocardial infarction (MI) is defined by the presence of myocardial necrosis in combination with clinical evidence of myocardial ischemia. Cardiac troponins are regulatory proteins within the myocardium that are released into the circulation when damage to the myocyte has occurred. Therefore, serum troponin is an exquisitely sensitive marker of myocardial injury and is necessary for establishing the diagnosis of MI.

CRITICAL THINKING

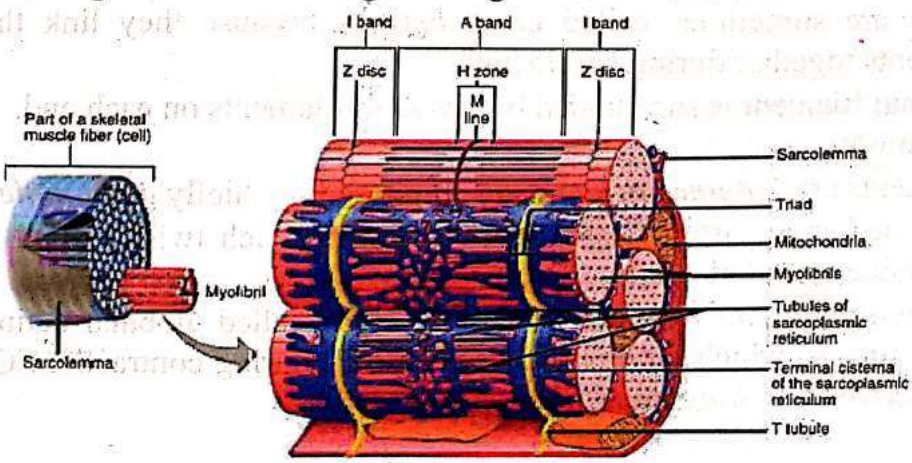
4. It is present in cardiac muscles but absent in smooth muscles:
A. Troponin B. Tropomyosin
C. Actin D. Myosin

Banding Pattern

- Each dark band is called ***A-band***; because it is anisotropic i.e. it can polarize visible light.
- The light band called ***I-band*** is isotropic or non-polarizing.
- Each A-band has a lighter strip in its mid-section called ***H-zone***.
- The H-zone is bisected by dark line called ***M-line***.
- The I-bands have mid line called ***Z-line***.
- A sarcomere is the region of a myofibril between two successive Z-lines and is the smallest contractile unit of muscle fiber.

T-Tubule, T System & Triad

- The sarcolemma of muscle fiber cell penetrates deep into the cell to form hollow elongated tube, the transverse tubule or T-tubule, the lumen of which is continuous with the extracellular fluid.
- The thousands of T-tubules of each muscle cell are collectively called ***T-system***.
- It extends and encircles the myofibril at the level of Z-line or A-I junction.
- The T-tubule and the terminal portion of the adjacent envelope of sarcoplasmic reticulum form triads at regular interval along the length of the fibril.



Initiation of Muscle Contraction

- Muscle contraction is initiated by nerve impulse arriving at the ***neuromuscular junction***. All the fibers innervated by a single motor neuron are a ***motor unit*** and contract simultaneously.
- Nerve impulse from sarcolemma penetrates into the muscle fiber through T-tubule.
- Then it is carried through the T-tubule to the adjacent SR.
- The ***calcium gates*** of sarcoplasmic reticulum open releasing calcium in cytosol.
- Calcium ions bind with the troponin molecules of thin filaments. This has the effect of displacing the tropomyosin and exposing the binding sites for the myosin.
- Once the myosin head has become attached to the actin filament, ATP is hydrolyzed and the bridges goes to its cycle and result in muscle contraction.
- ***Rigor Mortis*** is stiffening of the body after death. Since ATP is required to break the bond between actin and myosin, which get deficient after death, thus the bridges can't be broken, and the body gets stiff.

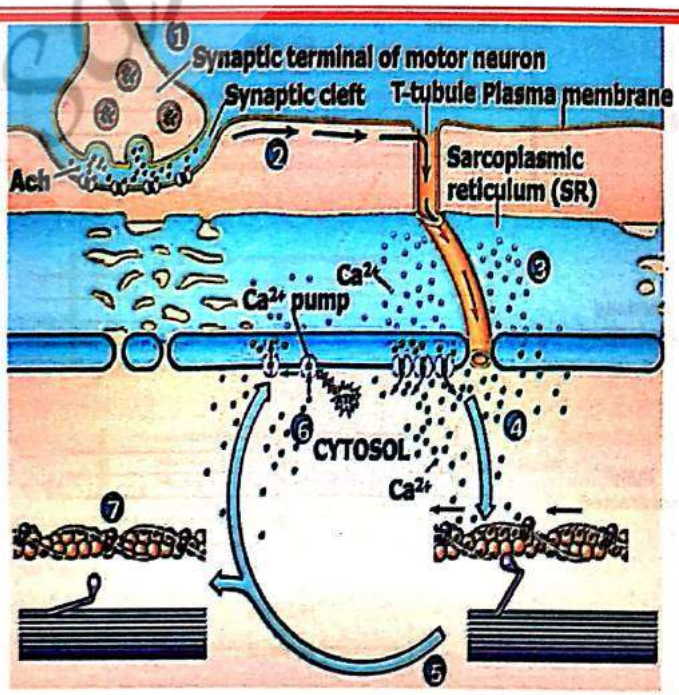
CRITICAL CONCEPT!

Medico-legal Importance of Rigor Mortis: Rigor mortis is useful in determining the time of death. Onset of stiffness starts between 10 minutes and 3 hours after death, depending upon the condition of the body and environmental temperature and time of death. If the body is active or environmental temperature is high at the time of death, the stiffness sets in quickly.

CRITICAL THINKING

5. Resolution of rigor mortis starts three days after death, the possible reason is?

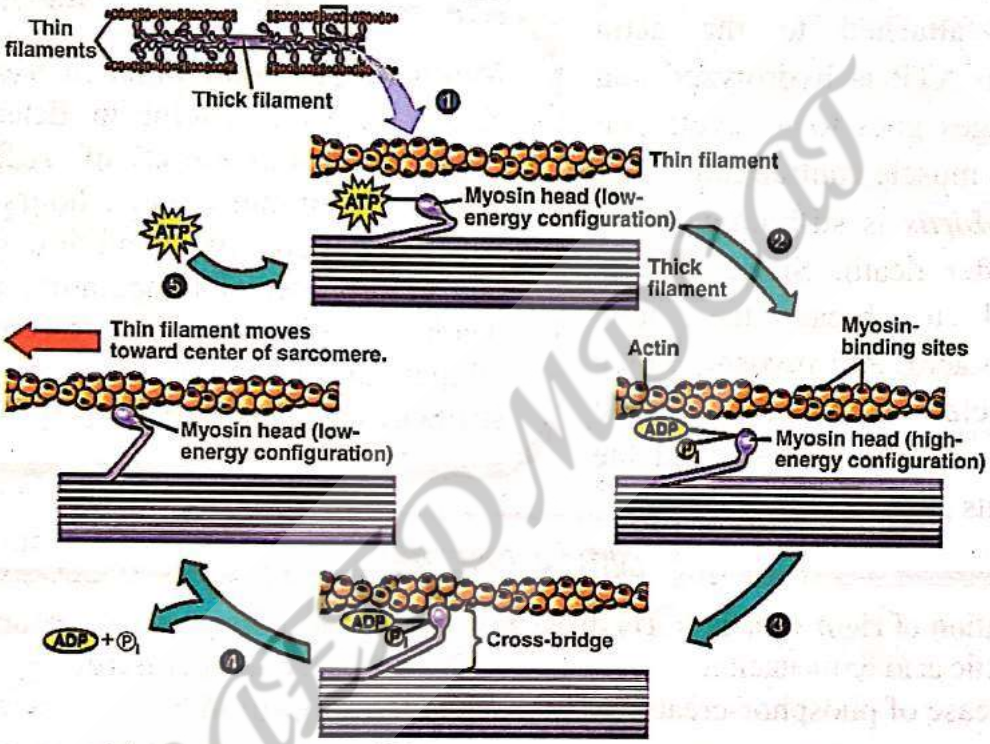
A. Lactic acid fermentation
B. Decreased temperature
C. Release of phosphor-creatin
D. Decomposition

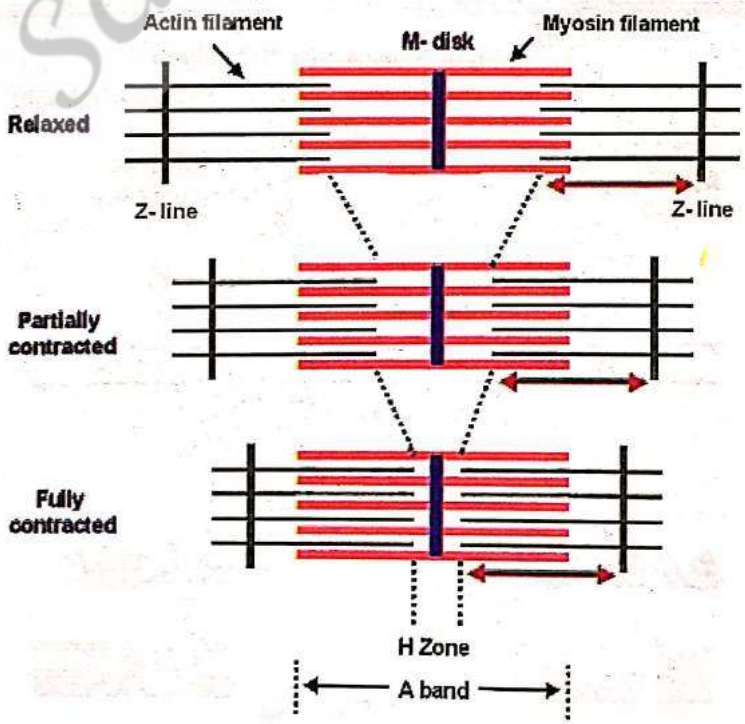


SLIDING FILAMENT MODEL AND ENERGY FOR MUSCLE CONTRACTION

H. Huxley and A.F. Huxley suggested this model of muscle contraction. Its salient features are given below:

- When muscle fiber contract, the ***thin and thick filaments undergo shifting***.
- Thin filaments slide past the thick filaments.
- Actin and myosin filaments overlap to greater degree.
- ***The I-band reduces in length.***
- ***Z-lines get closer.***
- ***H-zone disappears.***
- Length of A-band remains unchanged.
- Actin filaments come close to each other.





All or None Response

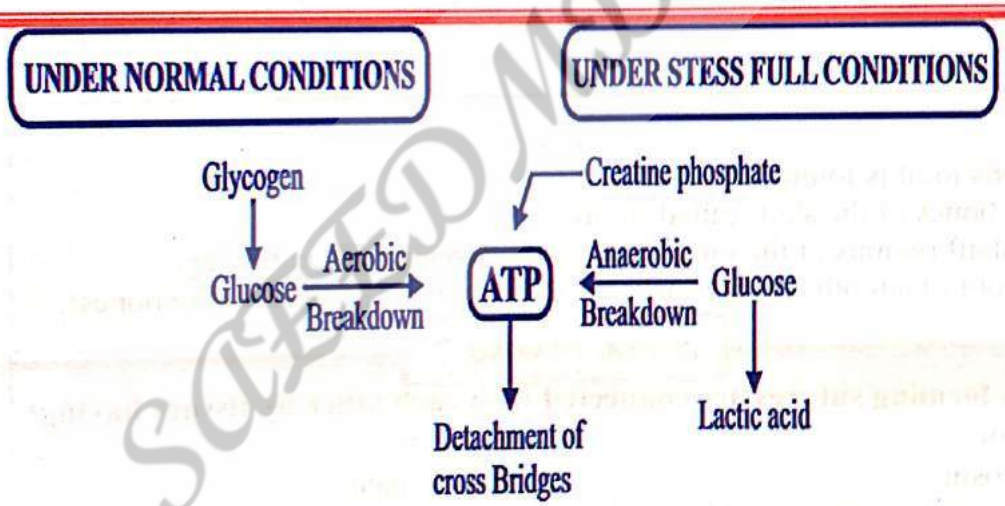
- All the fibrils of a muscle fiber will contract collectively in a particular contraction.
- However, the degree of contraction depends upon the number of participating fibers.

Energy for Muscle Contraction

- Energy for muscle contraction comes from ATP. Supply of ATP is maintained by the aerobic breakdown of glucose in muscle cell, which comes from stored glycogen in the cell.
- When more energy is required due to high metabolism, it is provided by another energy storing substance called creatine phosphate.
- Sometimes during oxygen deficiency or very high metabolic activity (such as prolonged or strenuous muscular activity), ATP requirement is met by anaerobic breakdown of glucose into lactic acid. Lactic acid accumulation causes muscle fatigue. At rest, 1/5 of lactic acid is broken aerobically and its energy is used to change the remaining 4/5 lactic acid into glucose.

CRITICAL THINKING

6. **How many ATP/s is/are required for one cycle of muscle relaxation and contraction?**
 A. 2 B. 1
 C. 3 D. 4



Effect of Exercise on Muscles

- Increase in size of the muscle.
- Increase in its strength.
- More efficient and fatigue resistant.
- Capillaries surrounding muscle fibers and mitochondria in it increases
- Synthesize more myoglobin.

CRITICAL THINKING

7. **ATP produced within cell is not used for:**
 A. Movement of calcium ions back to SR
 B. Muscle contraction
 C. Muscle relaxation
 D. Movement of calcium ions into sarcoplasm

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JOINTS

"A joint or articulation is a place where bone and bone or bone and cartilage come together."

- The scientific study of the structure and function of joints is called arthrology.

Classification of Joints

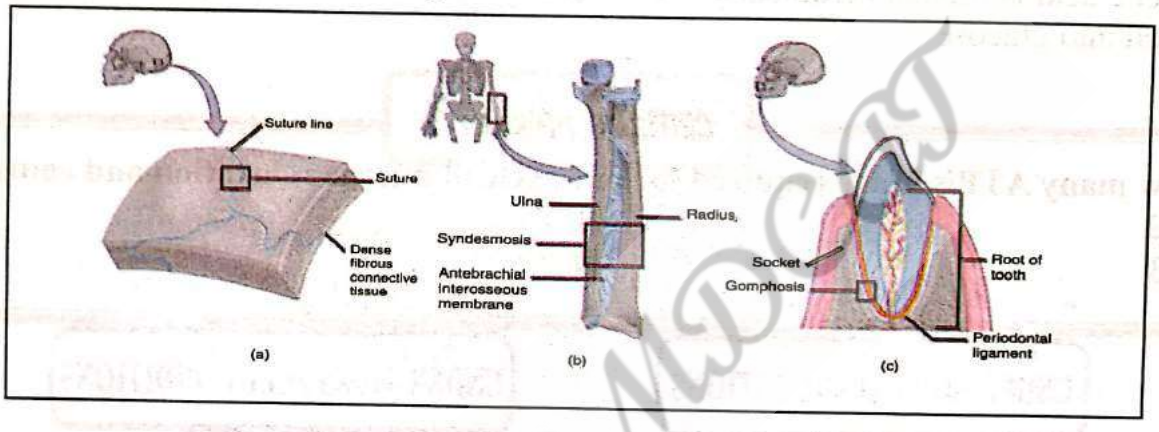
- The joints are classified as;

1. Fibrous Joints

- When the adjacent bones are directly connected to each other by fibrous connective tissue consisting mainly of collagen, it is called fibrous joint.

Characteristics

- In this joint the bones do not have a joint cavity between them.
- The gap between the bones may be narrow or wide.



Examples

Fibrous joint is found between:

(a) Most bones of the skull called suture.
(b) The shaft regions of the long bones in the forearm and in the leg.
(c) The root of a tooth and the socket in the maxilla or mandible (jawbones).

CRITICAL THINKING

8. Bones forming sutures are connected with each other by tissues having:

A. Titin B. Actin
C. Myosin D. Collagen

2. Cartilaginous Joints

- At a cartilaginous joint, the adjacent bones are united by cartilage, a tough but flexible type of connective tissue.

Characteristics

- These types of joints lack a joint cavity and involve bones that are joined together by either hyaline cartilage or fibrocartilage.
- Cartilaginous joints allow little movement.

Examples

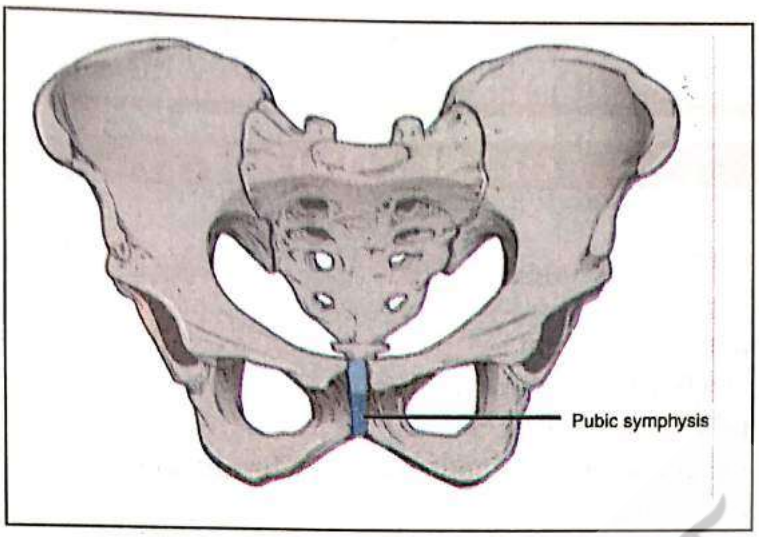
(a) Costal cartilages that attach ribs to the sternum.
(b) Pubic symphysis and intervertebral disc.

CRITICAL CONCEPT!

Epiphyseal Closure:

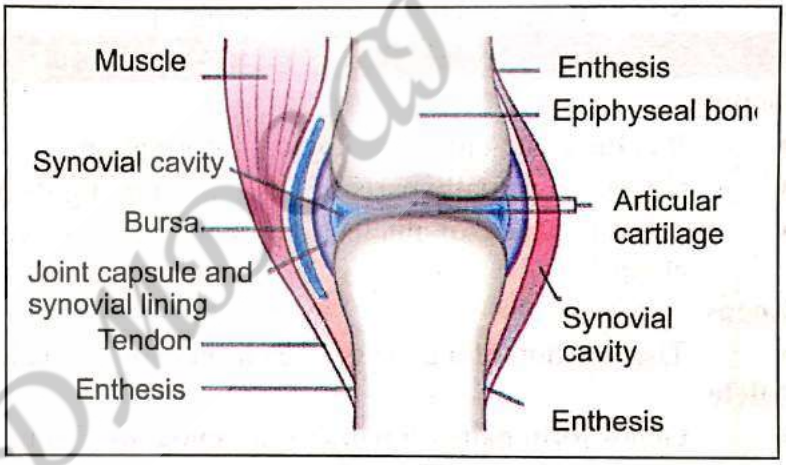
The epiphyseal plate or growth plate is a cartilaginous or strong elastic section at the tip of the long bones of the body. Located in the metaphysis, the broader portion on each end of the bone, these sections allow the bones to lengthen as the body develops. Without this plate the body would be unable to grow taller. Epiphyseal closure or the stoppage of bone growth occurs between the ages of eighteen and twenty-five.

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3. Synovial Joints

- The ends of bones are covered with hyaline cartilage and held together by a surrounding, tube like capsule of dense fibrous tissue.
- The joint capsule is composed of an outer layer of ligaments and an inner lining of synovial membrane, which secretes **synovial fluid**.



Characteristics

- They are freely movable joints.

Examples:

(a) Hinge joint
(b) Pivot joint
(c) Ball-and-socket joint
(d) Gliding joint

DISORDERS OF HUMAN SKELETON

ARTHRITIS

- It is the inflammation of joints.

Symptoms

- The typical symptoms of arthritis include pain after walking which may later occur even at rest, creaking sounds in joint, difficulty in getting up from a chair and pain on walking up and down stairs.

Types of Arthritis

There are different types of arthritis.

1. Osteoarthritis

- It is a progressive disease in which the articular cartilages gradually soften and disintegrate. It affects knee, hip and intervertebral joints.

2. Rheumatoid arthritis

- It is the result of an autoimmune disorder in which synovial membrane becomes inflamed due to faulty immune system.

3. Gouty arthritis

- It results from a metabolic disorder in which an abnormal amount of uric acid is retained in the blood and sodium urate crystals are deposited in the joints. Example: The most common joint affected is the joint of the big toe.

SCIENCE ACADEMY

TOPIC-13 »

VARIATION & GENETICS / INHERITANCE

COURSE CONTENT

- Basic Terms
- Mendelian Inheritance
- Law of Segregation
- Law of Independent Assortment
- Multiple Alleles (ABO Blood Group System)
- Gene Linkage and Crossing Over
- Recombination Frequency and Genetic Map of Chromosome
- Sex Linkage in *Drosophila*
- Sex Linkage in Humans (Hemophilia)

BASICS TERMS

Gene

- It is the basic unit of biological information.
- Genes are actually parts of DNA comprising its basic sequence.
- It is sequence of nucleotides that specifies sequence of amino acids in a polypeptide chain.

Locus

- The position of a gene on the chromosome is called its locus.

Allele

- Genes form pairs on pairs of homologous chromosomes.
- One member of a gene pair is located on one homologue and the other member on the other homologue.
- Partners of a gene pair are called alleles.
- Each allele of a gene pair occupies the same gene locus on its respective homologue.
- Both alleles on one locus may be identical or different from each other.

Dominant Allele

- Such an allele that masks the effect of other allele in a pair is called dominant allele and such trait is called dominant trait.
- For example, in pea plant, round (R) is dominant over wrinkled (r).

Recessive Allele

- Such an allele that is masked by another allele in a gene pair is called recessive allele and such trait is called recessive trait.
- For example, in pea plant, green (y) is recessive while yellow (Y) is dominant.

Gene Pool

- All the genes/alleles found in a breeding population at a given time are collectively called the gene pool.
- It consists of all the alleles at all genes loci in all individuals of the population.
- For a diploid species, each locus is represented twice in a genome of the individual who may be either homozygous or heterozygous.

Phenotype

- Physical appearance of a trait is called phenotype.

SEED Mocat

- For example, round and wrinkled are phenotypes of seed shape as the shape is a trait.

Genotype

- Genotype is the genetic complement i.e. the genes in an individual for a particular trait.
- For example, genotype of AB blood group is I^AI^B.

Homozygous

- When both alleles of a gene pair in an organism are same, the organism is homozygous for that gene pair.
- An individual with homozygous genotype is called homozygote or true breeding.
- For example, RR is genotype of homozygous round seeded pea plant.

Heterozygous

- If both alleles of a gene pair are different from each other, the organism is heterozygous for that gene pair.
- An individual with heterozygous genotype is called heterozygote or hybrid.
- For example, Rr is genotype of heterozygous round seeded pea plant.

MENDELIAN INHERITANCE

Selection of Pea Plant

Mendel selected pea plant (*Pisum sativum*) as experimental material due to following reasons:

- Its flowers were hermaphrodite. It was normally self-fertilizing but could be cross fertilized.
- It has short generation time.
- It has many sharply distinct traits.

Selection of Pea Plant

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CRITICAL CONCEPT!

Mendelian Traits:

Mendel's seven traits were on total four chromosomes.

Trait	Chromosome Number
Seed Shape	7
Stem Length	4
Seed Color	1
Flower color	1
Pod Color	5
Pod Shape	4
Position of Flower	4

Contrasting Traits Studied by G. Mendel

Character	Dominant Trait	Recessive Trait
Stem length	 Tall	 Dwarf
Pod shape	 Inflated	 Constricted
Seed shape	 Round	 Wrinkled
Seed colour	 Yellow	 Green
Flower position	 Axial	 Terminal
Flower colour	 Purple	 White
Pod colour	 Green	 Yellow

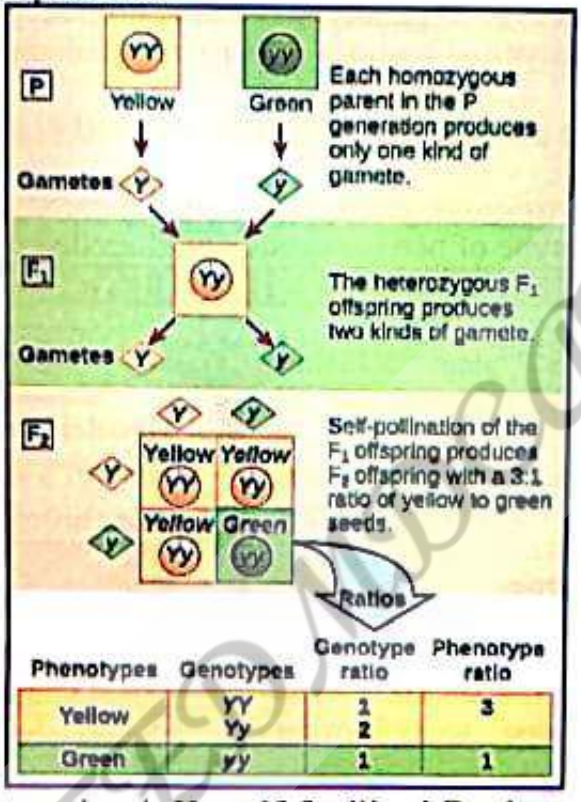
LAW OF SEGREGATION

Introduction

"The two co-existing alleles for each trait in an individual segregate (separate) from each other at meiosis, so that each gamete receives only one of the two alleles. Alleles unite again at random fertilization of gametes when zygote is formed".

- Law of segregation was developed through ***monohybrid cross*** (varying in one trait).

Phenotypic and Genotypic Expression



Phenotypes	Genotypes	Genotype ratio	Phenotype ratio
Yellow	YY Yy	1 2	3
Green	yy	1	1

- Mendel proceeded a step ahead. He self-fertilized F_2 plants to get the F_3 generation. He observed that 1/3 of F_2 round produced only round (appeared true of pure breeding like P_1 round), while 2/3 of F_2 round produced both round and wrinkled in 3:1 (appeared non-pure breeding like F_1 round). But F_2 wrinkled produced only wrinkled (pure breeding).

Results

- Based upon these observations, Mendel concluded that each contrasting form (phenotype) of a trait, e.g., roundness or wrinkledness of seed was determined by ***particulate hereditary factors***, which he called "***elementens***" (now called genes).
- These factors carrying hereditary information were transmitted from parents to offspring through gametes.
- Each pea plant had a pair of these factors (now called ***alleles***, the alternative form of gene on the same locus).
- One derived from the male parent and other from the female parent.
- Yellow is dominant over green.
- ***Phenotype*** ratio of F_2 generation is ***3:1***.
- ***Genotype*** ratio of F_2 generation is ***1:2:1***.

Test Cross

It is a mating in which an individual showing a dominant phenotype is crossed with an individual showing its recessive phenotype.

Significance

Details

- If round is crossed with wrinkled seeded plant and all offspring are round seed producing, then round of P_1 will be homozygous.
- If round is crossed with wrinkled seeded plant and offspring are obtained in 1:1 then round of P_1 will be heterozygous.

CRITICAL THINKING

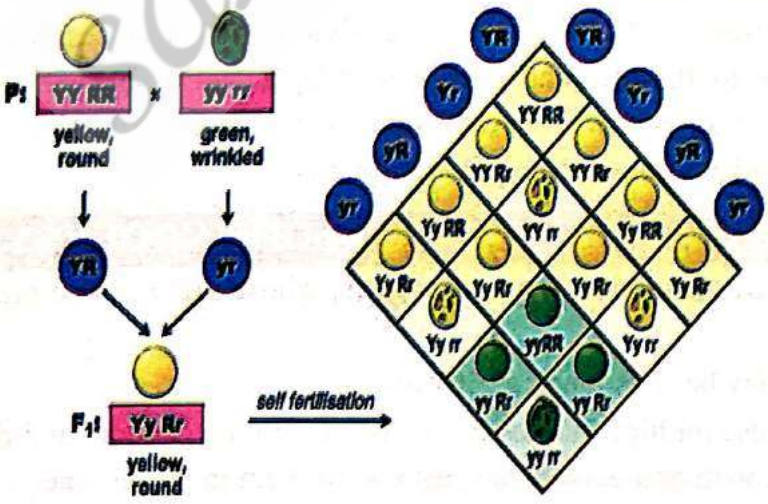
1. **Suppose growth hormone gene has two alleles. One allele has locus designated as 11Ai reduces growth of bones than its counterpart allele present at locus designated as 11Aii of bones shows more growth. Expression of later allele would be termed as:**
 A. Complete dominance B. Epistasis
 C. Incomplete dominance D. Codominance
2. **Mendel's law of independent assortment may not be applicable on which of the following contrasting pair of traits?**
 A. Seed shape and stem length B. Stem length and pod shape
 C. Pod color and pod shape D. Seed color and seed shape

LAW OF INDEPENDENT ASSORTMENT

"When two contrasting pairs of traits are followed in the same cross, their alleles assort independently into gametes".

- The distribution of alleles of one trait into gametes has no influence on the distribution of alleles of the other trait.
- Law of independent assortment was developed by studying dihybrid crosses (varying in two traits).

Phenotypic & Genotypic expression



Probability and Product Rule

- Probability is the chance of an event to occur e.g. in F_2 offspring of a monohybrid cross the independent chance for a seed to be round is 3/4.

- When two independent events are occurring simultaneously like in dihybrid cross, the ratio of each joint phenotypic combination can be obtained by multiplying the probabilities of individual phenotypes. It is called product rule.

Event No.1	Event No.2	Both Events at a Time
Seed Shape	Seed Colour	Seed Shape & Colour
Independent Probability	Independent Probability	Joint Probability
Round = 3/4	Yellow = 3/4	Round Yellow = 3/4 x 3/4 = 9/16
Round = 3/4	Green = 1/4	Round Green = 3/4 x 1/4 = 3/16
Wrinkled = 1/4	Yellow = 3/4	Wrinkled Yellow = 1/4 x 3/4 = 3/16
Wrinkled = 1/4	Green = 1/4	Wrinkled Green = 1/4 x 1/4 = 1/16

Limitations of Law of Independent Assortment

- Genes are located on chromosomes at specific loci. Independent assortment of genes depends upon independent assortment of their chromosomes.
- All the genes present on a homologous pair of chromosomes are linked to each other in the form of a linkage group. These cannot assort independently.
- Those alleles assort independently whose alleles are riding non-homologous chromosomes.

Usefulness of Law of Independent Assortment

i) Mendel's law of independent assortment explains that if two parents have unique set of traits which are desired to express in one individual, so it is possible only because of independent assortment.

ii) Furthermore, if two parents have such traits which they do not want to be expressed in their offspring. This is also possible only because of independent assortment.

Scope of Independent Assortment in Variation

i) Beside mutation and crossing over (which are sources of variation), independent assortment of traits is also a major source of variations in successive generations.
It is only due to the crossing over and independent assortment of the traits that the characteristics may appear in new combination in next generation which is often seems necessary for adaptations in varying environment.

MULTIPLE ALLELES (ABO BLOOD GROUP SYSTEM)

- All such altered alternative forms of a gene, whose number is more than two are called multiple alleles.
- Some genes may have as many as 300 alleles.
- Any two of these multiple alleles can be present in the genome of a diploid organism, but a haploid organism or a gamete has just one of them in its genome.
- Gene mutations may produce many different alleles of a gene.

ABO Blood Group System

- ABO blood group is first discovered multiple allelic blood group system in man.

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- This blood group system is encoded by a single polymorphic gene I (which stands for isohaemagglutinogen) on chromosome 9. It has three multiple alleles 'I^A', 'I^B' and 'I'.
- Allele 'I^A' specifies production of antigen 'A', allele 'I^B' specifies production of antigen 'B'.
- Alleles 'I^A' and 'I^B' are co-dominant for each other while completely dominant over 'I'.

Phenotypes & Genotypes

Phenotype	Genotype	Antigen	Antibody
A	I^AI^A, I^Ai	A	Anti-B antibody
B	I^BI^B, I^Bi	B	Anti-A antibody
AB	I^AI^B	A & B	No Antibody
O	Ii	No	Anti-A antibody Anti-B antibody

Transfusion Principle

- When transfusions are carried out between two incompatible (different) blood groups, antigens of donor react with the antibodies (also called ***agglutinins***) of the recipient, then the red blood cells clump with one another.
- The clumping of red blood cells is known as ***agglutination***. Therefore, the transfusions are carried out on the basis of donor's antigens and recipient's antibodies.

CRITICAL CONCEPT!

Blood Transfusion in Patients with Bombay Phenotype:
When individuals with the Bombay phenotype need blood transfusion, they can receive only autologous blood or blood from another Bombay blood group. Transfusing blood group 'O' red cells to them can cause a fatal hemolytic transfusion reaction.

Blood Transfusion

Blood Group	Donated To	Receives From
A	A, AB	A, O
B	B, AB	B, O
AB	AB	A, B, AB, O
O	A, B, AB, O	O

CRITICAL THINKING?

3. What is incorrect about ABO blood groups system?

	Blood Group	Antigen	Antibody	Genotype	Donor for	Recipient of
A.	A	A	Anti B	I^AI^A	A, AB	A, O
B.	B	B	Anti A	I^BI^B	B, AB	B, O
C.	AB	AB	No	I^AI^B	A, AB, B	AB
D.	O	No	Anti A and Anti B	ii	A, AB, B, O	O

4. If father is homozygous for blood group 'A' and mother is 'O', and both are carrier for H–gene, then probability of phenotypically 'O' child in their progeny will be:

A. 0
B. 25%
C. 50%
D. 100%

GENE LINKAGE AND CROSSING OVER

Gene Linkage

- Phenomenon of staying together of all the genes of a chromosome is called ***gene linkage.***
- Gene linkage is a physical relationship between genes.
- A chromosome carries its linked genes en block in form of linkage group.
- The number of linkage groups corresponds to the number of homologous pairs of chromosomes. Man has 23 linkage groups.

Types of Gene Linkage

i. **Autosomal linkage**
If genes are linked on autosomes, their linkage is called ***autosomal linkage.*** Similarly,

ii. **Sex Linkage**
If genes are linked on sex chromosome, their linkage is called ***sex linkage.***

Detection of Gene Linkage

- Gene linkage can easily be detected by ***performing a test cross*** between two gene pairs (dihybrid test cross). In such type of test cross, a heterozygous individual for two traits (F_1) is back crossed with its recessive parent (P_1).

Conclusion

i. If all four phenotypic combinations (parental and recombinants) are produced in equal 1:1:1:1 ratio, then there would be ***no linkage*** between the genes.

ii. If this ratio is deviated i.e., more parental types and less recombinant types, this indicates the ***incomplete or partial linkage.***

iii. But if only parental types are produced, ***complete or tight linkage*** is believed. In a typical dihybrid cross, the complete or tight linkage inhibits the outcome of recombinant types and disturbs 9:3:3:1 ratio of independent assortment, as a result, only parental combinations are produced in 3:1.

Examples

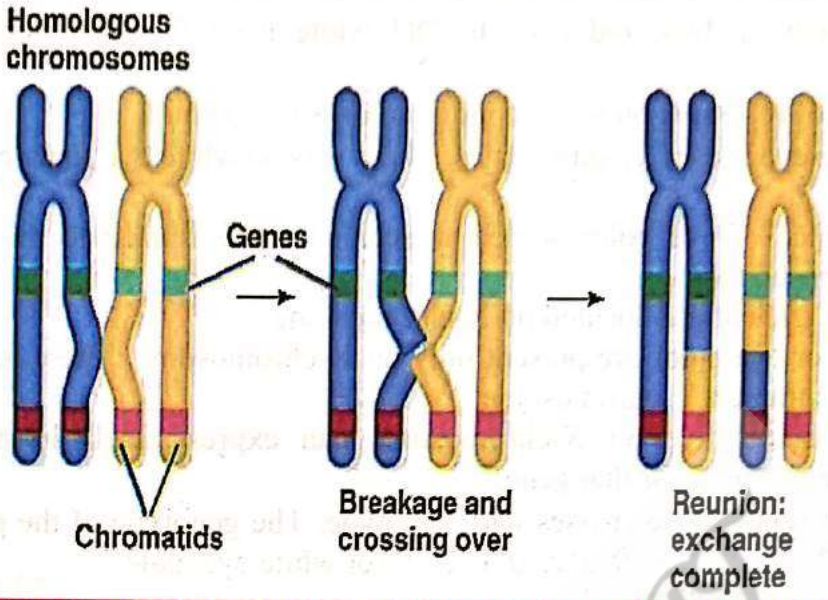
- Genes for ***color blindness, haemophilia,*** and ***gout*** etc. form one linkage group on human X-chromosome.
- Gene for ***sickle cell anaemia, leukemia*** and ***albinism*** etc. form linkage group on human chromosome 11.

Crossing Over

Crossing over is an exchange of segments between non-sister chromatids of homologous chromosomes during meiosis.

- Linked genes can be separated by ***crossing over.*** Closer the two gene loci, more strongly their genes linked. The farther apart two genes lie; greater are chances of their separation through crossing over.
- Crossing over minimizes the chances of gene linkage.

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RECOMBINATION FREQUENCY AND GENETIC MAP OF CHROMOSOME

- Cross over or recombination frequency is the proportion of recombinant types between two gene pairs as compared to the sum of all combinations.
- The recombination frequencies between two linked genes can be calculated by backcrossing the heterozygote to a homozygote double recessive.
- Its value is directly proportional to distance between the linked gene loci.
- Chances of crossing over are more if linked genes are present at distance.
- Genes can be mapped on a chromosome on the basis of their recombination frequencies.

SEX LINKAGE IN *DROSOPHILA*

- T. H. Morgan (1910) provided experimental evidence in support of chromosomal theory of heredity through discovery of sex linkage in *Drosophila*.

Reasons for Selection of *Drosophila*

Drosophila is a very useful organism for genetic studies for many reasons. For example;

(i) Easy collection & culturing
(i) Sexual dimorphism
(ii) Short generation time
(iii) Excellent for genetic studies
(iv) Part of human genome project

Morgan's Experiments and Crosses

- Morgan raised cultures of *Drosophila* flies to study different traits, such as colour of the eye.
- Normal fruit flies, the ***wild type***, have bright red eyes. One of his coworkers Calvin Bridges, observed an unusual white eye mutant male fly.

Step 1: Normal Cross

Morgan mated white eyed male with a wild type red eyed female. All 1237 offspring of this cross had red eyes. Morgan concluded that red eye is dominant trait.

Step 2: Normal Cross

Morgan allowed males and females of F_1 generation to mate and produce F_2 generation. He counted 2459 red eyed females, 1011 red eyed males and 782 white eye males among F_2.

Observations

Different observations got by this cross were;

- Offspring produced due to this cross were red-eyed females, red-eyed males and white-eyed males.

- The proportion of 3470 red eyed to 782 white eyed flies did not perfectly fit into Mendelian 3:1 ratio.
- The number of recessive phenotype individuals was too small.
- All the white-eye flies were only males. There was no white eye female in F_2.

Conclusion

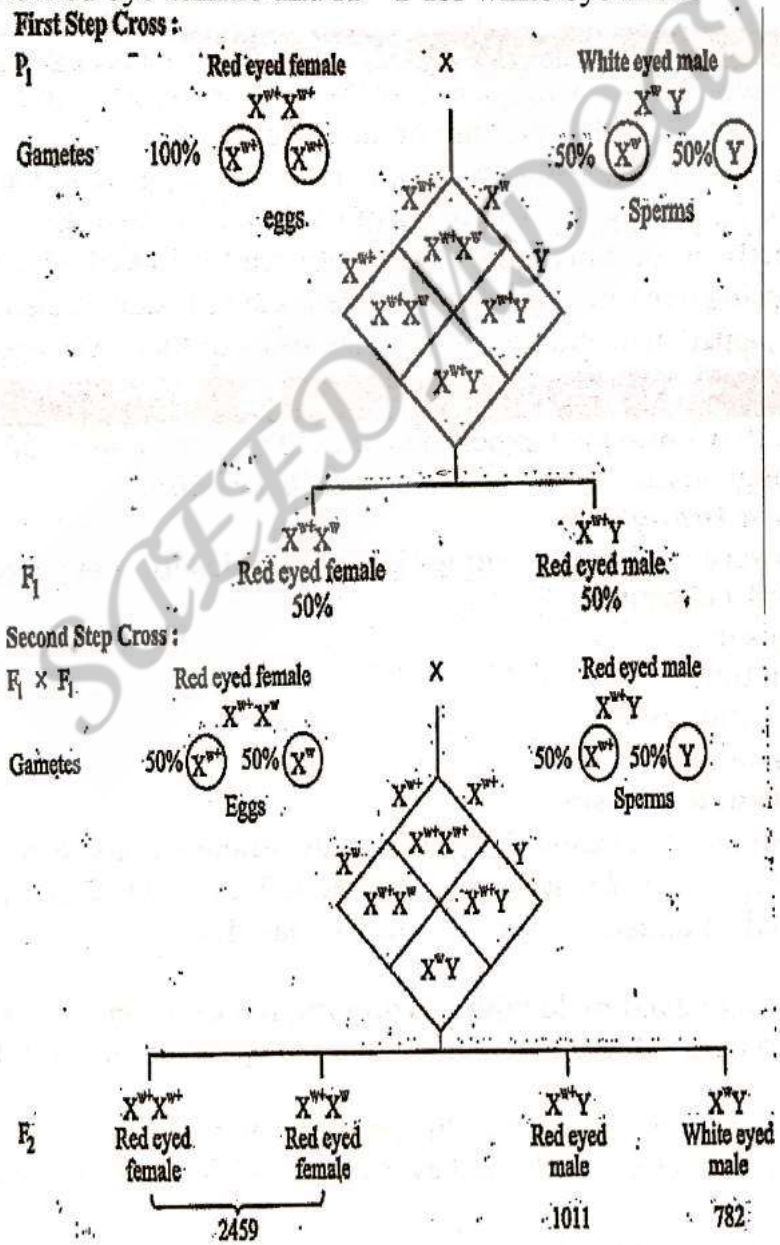
The inheritance of eye color somehow seemed to be related to the sex of offspring. Morgan proposed that;

(i) The gene for eye color is located on X-chromosome.

(ii) The alleles for eye color are present only on X-chromosome. There is no corresponding allele for this trait on Y-chromosome.

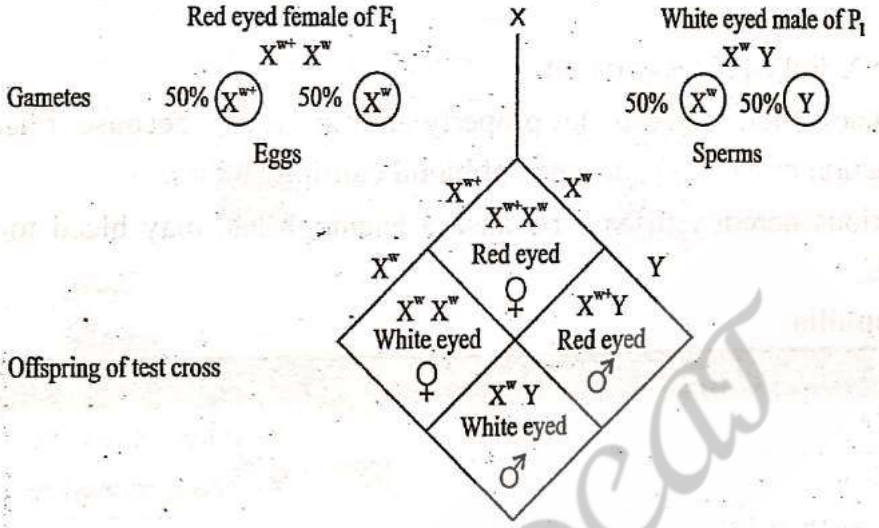
(iii) Single recessive allele on X-chromosome can express itself in males because Y-chromosome is empty for that gene.

- Now we can relate these crosses with genotype. The genotype of the parents of P_1 cross were $X^{W+}X^{W+}$ for red eye female and $X^{W}Y$ for white eye male.



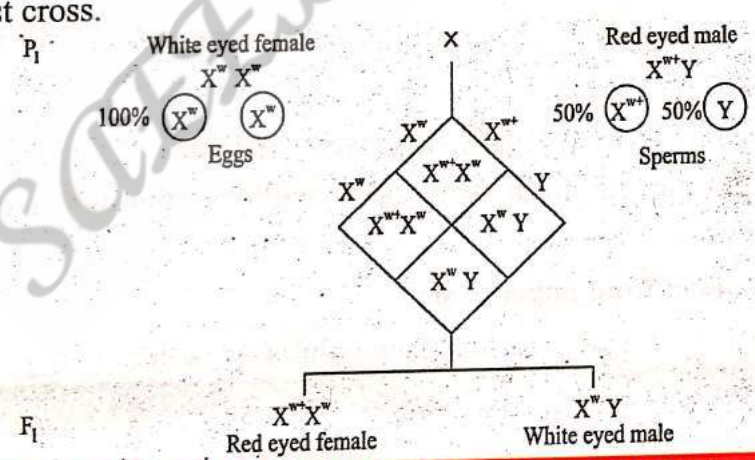
Step 3: Test Cross

- Morgan wanted to test his hypothesis. He crossed the P_1 white eyed male (X^wY) with one of its own daughters (the red-eyed heterozygous female from F_1 generation).
- Out of total offspring of this cross, half female offspring had red eyes and half had white. Similarly, half the males had red eyes and half had white.



Step 4: Reciprocal Cross/ Confirmatory Test

- Appearance of white eyed female provided an opportunity for a further confirmatory test.
- Morgan mated a white-eyed female with a red-eyed male. All female offspring had red eyes and all male offspring had white eyes.
- When F_1 red-eyed females and white-eyed males were mated to produce F_2, then half of the F_2 females had red eyes and half white eyes.
- Similarly, half of the F_2 males had red eyes and half white. This F_1 x F_1 cross was exactly like step 3 test cross.



SEX LINKAGE IN HUMANS (HEMOPHILIA)

- A trait whose gene is present on X chromosome is called ***X-linked trait***. X-linked traits are commonly referred as sex-linked traits.
- ***X-linked recessive traits*** are common in male while ***X-linked dominant traits*** are common in female.
- X-linked traits follow ***zig zag path*** while Y-linked traits are transmitted in ***straight way***.

CRITICAL CONCEPT!

Two humans typically share around 99.9% of the same genetic material. It's the 0.1% of the material that makes them different. Humans share about 90% of genetic material with mice and 98% with chimpanzees.

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- Genes located on Y chromosomes are called Y-linked genes and their traits are called ***y-linked traits***.
- Such traits whose genes are located on both 'X' and 'Y' chromosomes are called 'X' and 'Y' linked or ***pseudoautosomal traits*** such genes are called 'X' and 'Y' linked genes.

Haemophilia

- It is a rare X-linked recessive trait.
- Hemophiliac's blood fails to clot properly after an injury, because it has either reduction or malfunction or complete absence of blood clotting factors.
- It is a serious heredity disease because a haemophiliac may bleed to death even from minor cuts.

Types of Haemophilia

Type	Occurrence	Factor	Genetics
A	80%	VIII	X-linked recessive
B	20%	IX	X-linked recessive
C	Less than 1%	XI	Autosomal recessive

- Haemophilia 'A' and 'B' are ***non-allelic recessive sex-linked*** but haemophilia 'C' is an ***autosomal recessive trait*** (***Autosome 4***).
- Haemophilia 'A' and 'B' have more chances in male as compared to female while haemophilia C has equal chances in both male and female.

Genetics of Haemophilia A

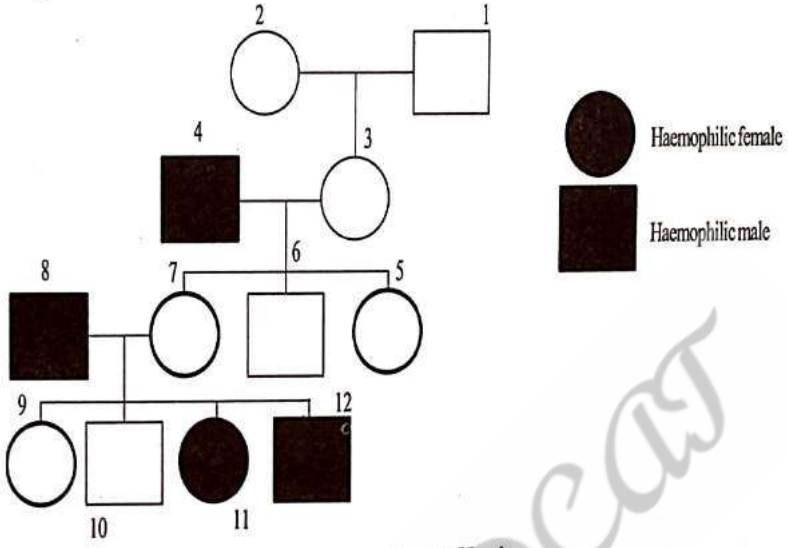
- A woman can suffer from 'haemophilia A' only when she is homozygous for the recessive allele.
- A man with just one recessive allele will display the trait.
- Haemophilia 'A' zig-zag from maternal grandfather through a carrier daughter to a grandson.
- It never passes direct from father to son.
- Gene for normal is 'H' and gene for 'haemophilia A' is 'h'.

Gender	Genotype	Phenotype
Female	X^HX^H	Normal
	X^HX^h	Normal but Carrier
	X^hX^h	Haemophilic
Male	X^HY	Normal
	X^hY	Haemophilic

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CRITICAL THINKING

5. **A pedigree of a family is given below. Find out the genotype of individual for hemophilia at position 5:**



A. X^HX^H
B. X^HX^h
C. X^hY
D. X^HY

Traits and Examples

Trait	Example
X-linked recessive	Hemophilia, colorblindness, testicular feminization syndrome
X-linked dominant	Hypophosphatemic or vitamin D resistant rickets
Y- linked trait	Maleness
Pseudoautosomal trait	Bobbing in insects
Sex limited trait	Milk yield in cow, beard in man
Sex influenced trait	Baldness

CRITICAL THINKING

6. **An X linked recessive trait which is characterized by difficulty of patient to rise to standing position:**
A. Testicular feminization syndrome
B. Colorblindness
C. Duchenne muscular dystrophy
D. Hypophosphatemic rickets

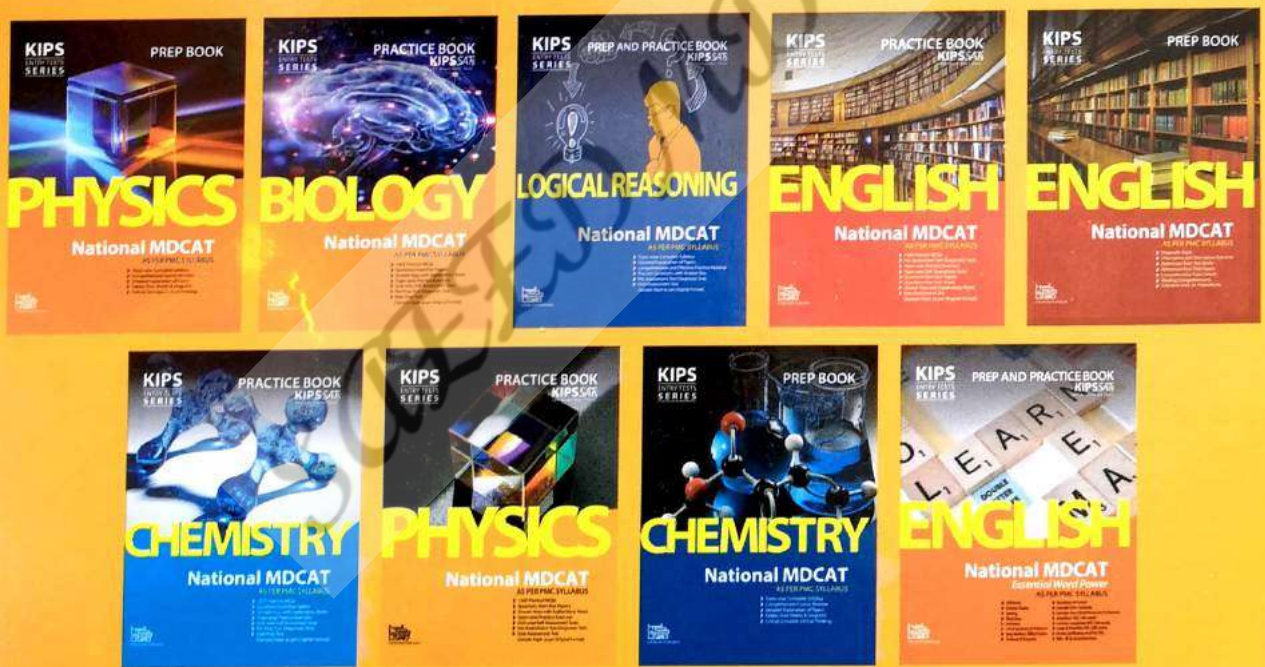
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